

(19) World Intellectual Property  
Organization  
International Bureau



(43) International Publication Date  
30 September 2004 (30.09.2004)

PCT

(10) International Publication Number  
**WO 2004/083631 A2**

(51) International Patent Classification<sup>7</sup>: **F03D**

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(21) International Application Number:  
PCT/GB2004/001176

(22) International Filing Date: 18 March 2004 (18.03.2004)

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(25) Filing Language: English

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(26) Publication Language: English

(30) Priority Data:  
0306075.3 18 March 2003 (18.03.2003) GB

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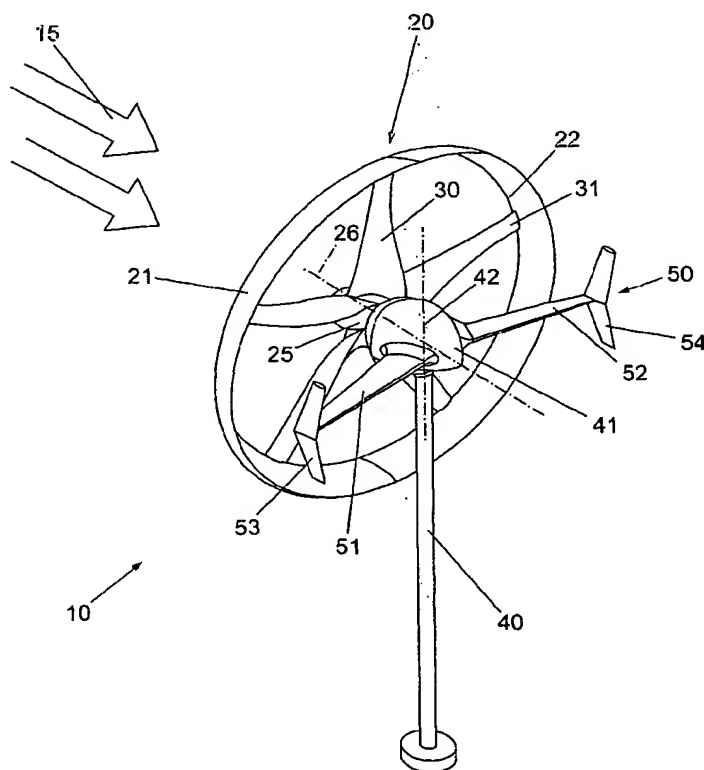
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[Continued on next page]

(54) Title: WIND TURBINE



(57) Abstract: There is described herein a rotor for a wind turbine comprising a plurality of radial blades and a ring-shaped aerofoil diffuser connecting the outer tips of the blades. Further there is described a wind turbine comprising said rotor and further comprising a nacelle and a mounting means adapted to allow rotation of the turbine and rotor about a directional axis perpendicular to the rotational axis, thus allowing the turbine to be oriented in the optimum direction depending on wind conditions. A furling means is disclosed to effect a change in orientation depending on wind speeds. A wind turbine system is also disclosed comprising: a wind turbine driven generator and means for providing a power output, the power output connected to a heating system, a grid-tie inverter or stand alone inverter adapted to supply power to local or grid power infrastructure, or an energy storage system. A method of controlling the level of power taken from a wind turbine; and a wind turbine comprising means for reducing the operating vibrations caused by harmonic resonance within the turbine, tower and mounting structure are also described.

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GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

**Published:**

— *without international search report and to be republished upon receipt of that report*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

18/pets  
14 SEP 20051 Wind turbine

2

3 The invention relates to wind turbines, and more  
4 particularly to a wind turbine for mounting on a  
5 roof and for use with a heating system (either  
6 domestic or commercial), energy storage system,  
7 electrical storage system or with a local or  
8 national electricity grid.

9

10 The UK government, under the Kyoto agreement, made a  
11 commitment to decrease CO<sub>2</sub> emissions by 10% by 2010  
12 and the Scottish Executive have set even more  
13 stringent environmental targets. Accordingly, there  
14 has recently been emphasis on renewable sources of  
15 energy. Analysis of energy demands shows that 47%  
16 of the UK's annual energy demand is from buildings,  
17 which contributes 40% of the UK's CO<sub>2</sub> emissions.  
18 The technology of the present invention will provide  
19 substantial economic benefits to over 33% of  
20 buildings and could reduce the UK's CO<sub>2</sub> emissions by  
21 as much as 13%.

22

CONFIRMATION COPY

1 Existing turbines of a size suitable for mounting on  
2 a roof to provide power are designed for smooth  
3 airflow only and will oscillate violently with the  
4 compressed and turbulent airflow found over, and  
5 around, buildings, creating noise and inefficient  
6 generation.

7

8 It is an object of the present invention to overcome  
9 one or more of the aforementioned problems.

10

11 According to a first aspect of the invention there  
12 is provided a rotor for a wind turbine comprising a  
13 plurality of radial blades and a ring-shaped  
14 aerofoil diffuser connecting the outer tips of the  
15 blades.

16

17 Preferably the aerofoil diffuser extends downstream  
18 from the outer tips of the blades. The outer tips  
19 of the blades may be connected to the diffuser at or  
20 near to the leading edge of the diffuser.

21

22 Preferably the aerofoil diffuser tapers outwards  
23 from the outer tips of the blades to form a  
24 substantially frusto-conical diffuser, the  
25 rotational axis of the frusto-conical diffuser is  
26 substantially aligned to the rotational axis of the  
27 blades.

28

29 Alternatively, at least a portion of the aerofoil  
30 diffuser extends upstream from the outer tips of the  
31 blades, the aerofoil diffuser tapers radially

1 outwards as it extends from the upstream end to the  
2 downstream end.

3  
4 Preferably the aerofoil diffuser is shaped such that  
5 it inhibits the partially axial and partially radial  
6 airflow from the blades, said airflow becoming  
7 circumferential when it contacts the aerofoil  
8 diffuser. Further preferably the shape of the  
9 aerofoil diffuser is such that there is a resultant  
10 improvement in the aerodynamic and acoustic  
11 characteristics of the blade and diffuser assembly  
12 when in rotation.

13  
14 Preferably the aerofoil diffuser is adapted to  
15 inhibit partly axial and partly radial airflow from  
16 the outer tips of the blades and divert said airflow  
17 to circumferential airflow during normal operation.

18  
19 Preferably the blades are inclined at an angle  
20 relative to a transverse rotor plane perpendicular  
21 to the rotational axis of the rotor. The angle of  
22 inclination may vary along the length of the blade.

23  
24 Preferably the angle of inclination of each blade is  
25 greater at an intermediate portion of the blade than  
26 at the outer tip of the blade. Preferably the blade  
27 is substantially parallel to the transverse rotor  
28 plane at the outer tip of the blade.

29  
30 According to a second aspect of the invention there  
31 is provided a wind turbine comprising a rotor  
32 according to the first aspect. Preferably the wind

1 turbine further comprises a nacelle and a mounting  
2 means adapted to allow rotation of the turbine and  
3 rotor about a directional axis perpendicular to the  
4 rotational axis. This allows the turbine to be  
5 oriented in the optimum direction depending on wind  
6 conditions.

7  
8 Preferably the wind turbine further comprises a  
9 furling means adapted to rotate the rotor about the  
10 directional axis so that the rotational axis is not  
11 parallel to the direction of airflow when the  
12 airflow speed is greater than a predetermined  
13 airflow speed.

14  
15 Preferably the furling means comprises a non-linear  
16 furling means adapted to provide no furling over a  
17 first lower range of airflow speed and a varying  
18 degree of furling over a second higher range of  
19 airflow speed. Preferably the furling means  
20 comprises at least two tail fins extending  
21 downstream of the diffuser. Preferably the furling  
22 means comprises two tail fins provided diametrically  
23 opposite each other, but more tail fins may be  
24 provided if required, providing the positions of the  
25 tail fins are balanced.

26  
27 Preferably one of the tail fins is a moveable tail  
28 fin hingedly mounted for rotation about a tangential  
29 hinge line. The moveable tail fin may be mounted on  
30 a mounting boom and the hinge line may be provided:  
31 at the connection point of the mounting boom and the  
32 nacelle, so that the mounting boom also rotates; at

1 the connection between the mounting boom and the  
2 moveable tail fin so that only the moveable tail fin  
3 rotates; or at any point along the length of the  
4 mounting boom.

5  
6 Additionally or alternatively, the tail fin may  
7 rotate about a horizontal axis under high winds  
8 resulting in a fin which folds about a horizontal  
9 axis.

10  
11 Preferably the moveable tail fin is rotationally  
12 biased by biasing means to an at-rest position in  
13 which the leading edge of the moveable tail fin is  
14 closer to the axis of rotation of the rotor than the  
15 trailing edge of the moveable tail fin, such that  
16 the moveable tail fin is angled at an at-rest attack  
17 angle to the axis of rotation of the rotor. The  
18 biasing means may be non-linear. Preferably the  
19 biasing means is adapted to hold the moveable tail  
20 fin in the at-rest position until the airflow speed  
21 reaches a predetermined speed. Preferably, as the  
22 airflow speed increases beyond the predetermined  
23 speed the moveable fin rotates and the attack angle  
24 decreases. This results in unbalanced aerodynamic  
25 loading on the wind turbine, so that the wind  
26 turbine rotates about its mounting axis to a furled  
27 position.

28  
29 According to a third aspect of the present invention  
30 there is provided a wind turbine system comprising:  
31 a wind turbine driven generator and means for  
32 providing a power output.

1

2 Preferably the system further comprises an  
3 electronic control system.

4 Preferably the system comprises a dump element  
5 comprising one or more energy dissipaters. The  
6 energy dissipaters may be in the form of resistive  
7 elements.

8

9 Preferably the dump element is in the form of a  
10 liquid storage vessel having electrical heating  
11 elements therein adapted to heat liquid in said  
12 storage vessel.

13

14 Preferably the control means may be adapted to  
15 supply electrical power to said one or more  
16 electrical heating elements when the power from the  
17 wind turbine exceeds a predetermined power. In one  
18 embodiment the liquid storage vessel is a cold water  
19 tank and the liquid is water. In another embodiment  
20 the heating element is a radiator.

21

22 Preferably this dump element is activated by the  
23 electronic control system when the power available  
24 from the wind exceeds the power take-off due to a  
25 loss or reduction of electrical load caused by the  
26 switching off, reduction or separation of the said  
27 electrical load.

28

29 Preferably said dump element is activated when the  
30 rotor speed increases above a defined "dump on"  
31 rotor speed caused by the imbalance of wind turbine  
32 rotor torque and wind turbine generator torque. The



1 said wind turbine rotor torque is dependent on wind  
2 speed and the said wind turbine generator torque is  
3 dependent on the electrical load.

4  
5 Further, said dump element serves to increase the  
6 wind turbine generator torque above the wind turbine  
7 rotor torque reducing the wind turbine rotor speed  
8 until it approaches or reaches an aerodynamic stall.  
9 The dump load is then released when the wind turbine  
10 rotor speed falls below a defined "dump off" rotor  
11 speed. The said "dump on" and "dump off" rotor  
12 speeds are defined proportionally to the power take-  
13 off thus reducing the generator torque.

14  
15 Preferably, the wind turbine system according to the  
16 present invention is provided with a control means  
17 in order to control the level of power taken from  
18 the wind turbine. For efficiency reasons the  
19 maximum power take-off from the wind turbine is  
20 approximately 60%, as given by the Betz limit. The  
21 control system is adapted to increase or decrease  
22 the power take-off from the wind turbine by a small  
23 amount and temporarily set the power take-off at  
24 this level. After a certain time period, the  
25 control system will measure the rotor speed of the  
26 wind turbine again and thus calculate the  
27 acceleration of the rotor. Additional measurements  
28 of rotor speed are then made after additional time  
29 periods. These are used to calculate the first,  
30 second and third order values, namely speed,  
31 acceleration/deceleration and the rate of change of  
32 acceleration/deceleration, to the said increase or

1 decrease in power take-off. A combination of the  
2 said first, second and third order values determines  
3 a change in the existing power take-off and the  
4 amount of power taken from the wind turbine is again  
5 adjusted. The above steps are repeated  
6 continuously.

7  
8 Preferably the system comprises a wind turbine  
9 according to the first or second aspects of the  
10 invention.

11  
12 The power output may be connected to a heating  
13 system further comprising a further liquid storage  
14 vessel,  
15 one or more electrical heating elements adapted  
16 to heat liquid in said further vessel, and  
17 control means adapted to control the supply of  
18 electricity generated by said generator to said one  
19 or more electrical heating elements.

20  
21 Preferably the further liquid storage vessel is a  
22 hot water tank and the liquid is water.

23  
24 Additionally or alternatively, the heating system  
25 comprises a plurality of electrical heating  
26 elements, and the control means is adapted to supply  
27 electrical power to a proportion of the electrical  
28 heating elements, the proportion being dependent  
29 upon the instantaneous electrical power generated by  
30 the generator.

31

1 Preferably the heating element in the further liquid  
2 vessel is enclosed by means of a tube. This tube is  
3 open on the underside thereof in order to allow  
4 water to flow from beneath the tube towards the  
5 heating element. The tube will enclose and extend  
6 over in essence the entire length of the heating  
7 element. The water near the heating element will be  
8 heated and will flow upwards due to natural  
9 convection. The presence of the tube will direct  
10 the heated water towards a zone near to or at the  
11 top of the vessel. The presence of the tube will  
12 enable the formation of different and separate  
13 thermally stratified heat zones within the further  
14 liquid storage vessel.

15  
16 Alternatively or additionally, the power output may  
17 be connected to a grid-tie inverter or stand alone  
18 inverter. Preferably the inverter is adapted to  
19 supply power to local or grid power infrastructure.

20  
21 Alternatively or additionally, the power output may  
22 be connected to an energy storage system.

23  
24 According to a fourth aspect of the present  
25 invention there is provided a method of controlling  
26 the level of power taken from a wind turbine  
27 comprising the following steps taken by a control  
28 means:

- 29 (a) increasing or decreasing the power take-off  
30 from the wind turbine by a small amount;  
31 (b) temporarily setting the level of power take  
32 -off;

- 1 (c) after a predetermined time period, taking a  
2 number of measurements of the rotor speed;  
3 (d) calculating the first, second and third  
4 order values, namely speed,  
5 acceleration/deceleration and rate of change  
6 of acceleration/deceleration respectively,  
7 to the said increase or decrease in power  
8 take-off;  
9 (e) adjusting the power taken from the wind  
10 turbine in response to the calculation.  
11  
12 Preferably steps (b) to (e) are repeated  
13 continuously.  
14  
15 Preferably the control means uses the following  
16 logic to determine the adjustment:  
17 (a) IF: there is a positive second order rotor  
18 speed response (acceleration) and an  
19 increasing rate of said acceleration  
20 (positive third order response) of the rotor  
21 speed; THEN: the control means causes an  
22 increase in the power take-off; OR  
23 (b) IF: there is a positive second order rotor  
24 speed response (acceleration) and decreasing  
25 rate of said acceleration (negative third  
26 order response) of the rotor speed; THEN:  
27 the control means causes an increase or  
28 alternatively no change in the power take-  
29 off; OR  
30 (c) IF: there is a negative second order rotor  
31 speed response (deceleration) and increasing  
32 rate of said deceleration (positive third

1           order response) of the rotor speed; THEN:  
2           the control means causes a reduction in the  
3           power take-off; OR  
4       (d) IF: there is a negative second order rotor  
5           speed response (deceleration) and decreasing  
6           rate of said deceleration (negative third  
7           order response) of the rotor speed; THEN:  
8           the control means causes an increase or  
9           alternatively no change in the power take-  
10          off.

11

12       Preferably the control means repeats the above steps  
13       to continue adjusting the power take-off to ensure  
14       that the power take-off is always maximised to the  
15       power available to the wind turbine which is  
16       dependent on the local wind speed at the rotor  
17       plane.

18

19       According to a fifth aspect of the invention there  
20       is provided a wind turbine according to the second  
21       aspect comprising means for reducing the operating  
22       vibrations caused by harmonic resonance within the  
23       turbine, tower and mounting structure.

24

25       Preferably the wind turbine is provided with a  
26       nacelle damping system. The nacelle damping system  
27       according to the invention will help to isolate the  
28       vibrations in the generator and turbine from the  
29       tower.

30

31       Preferably the wind turbine is provided with  
32       mounting brackets for mounting the turbine on a

1 surface, the brackets having a sandwich construction  
2 of visco-elastic materials and structural materials.

3

4 The mounting means can be of any cross-sectional  
5 shape, but is typically tubular. Preferably, the  
6 tower contains one or more cores of flexible  
7 material, such as rubber, with sections with a  
8 reduced diameter, which are not in contact with the  
9 tower's inner radial surface. These reduced  
10 diameter sections alternate with normal sized  
11 sections, which are in contact with the tower's  
12 inner surface.

13

14 This serves to absorb vibrations in the tower  
15 through the energy dissipated in the flexible core  
16 before they reach the mounting brackets. The rubber  
17 core thereby acts to control the system's resonant  
18 frequency out-with the turbine driving frequency by  
19 absorption of a range of vibration frequencies. By  
20 altering the cross-sectional shape and length of  
21 each of the reduced diameter sections, the system  
22 can be "tuned" to remove a range of vibration  
23 frequencies from the mounting structure.

24

25 The sandwich mounting brackets compliment the  
26 mounting means core design and suppress vibrations  
27 that come from the nacelle. The nacelle itself  
28 supports the generator through bushes designed to  
29 eliminate the remaining frequencies. These three  
30 systems act as a high/low pass filter where the only  
31 frequencies that are not attenuated are those out-  
32 with the operating range of the turbine.

1

2     Embodiments of the present invention will now be  
3     described with reference to drawings wherein:

4

5     Figs 1A and 1B show schematic views of two  
6     embodiments of the wind turbine according to the  
7     present invention;

8

9     Figs 2A and 2B show top views of two embodiments of  
10    the rotor and the furling device of the wind turbine  
11    according to Figs 1A and 1B respectively;

12

13    Fig 3 shows in detail an embodiment of one boom of  
14    the furling device according to the present  
15    invention;

16

17    Fig 4 shows the connection of the boom according to  
18    Fig 3 through the nacelle;

19

20    Figs 5A and 5B show the connection of the tip of the  
21    boom to the tail fin;

22

23    Fig 6 shows a schematic overview of a heating device  
24    for heating water which is adapted to be coupled to  
25    a wind turbine according to the present invention;

26

27    Fig 7 shows diagrammatically the working of the  
28    control system of the heating device according to  
29    Fig 6;

30

31    Figs 8A, 8B and 9A, 9B show a further embodiment of  
32    a heating device for heating water, which is adapted

1 to be connected to the wind turbine according to the  
2 present invention;

3

4 Fig 10 shows a cross-sectional view of the mounting  
5 means for the wind turbine according to the present  
6 invention, wherein the interior is provided with a  
7 vibration damping core;

8

9 Figs 11 and 12 show a cross-sectional view of the  
10 mounting means according to Fig 10 as alternative  
11 embodiments for the vibration damping core;

12

13 Fig 13 shows a schematic block diagram of a wind  
14 turbine system in accordance with the fourth aspect  
15 of the invention; and

16

17 Fig 14 shows a schematic block diagram of a wind  
18 turbine system in accordance with the fifth aspect  
19 of the invention.

20

21 In Figs 1A and 1B are shown possible embodiments of  
22 the wind turbine 10,110 according to the present  
23 invention is shown. The wind turbine 10,110  
24 comprises a rotor 20,120 having a core 25,125 and  
25 radial blades 30,130 extending from the core 25,125  
26 towards the outer tip 31 of the blades 30,130. The  
27 rotor comprises a radial aerofoil 21,121, attached  
28 to and encircling the rotor blades 30,130. The  
29 rotor 20,120, by means of the core 25,125, is  
30 rotationally fixed to a nacelle 41,141. The rotor  
31 20,120 is able to rotate about the rotational axis  
32 26. The nacelle 41,141 is rotationally mounted on



1 top of mounting means 40. The mounting means 40  
2 allow the wind turbine 10,110 to be fixed on a  
3 support (not shown). The nacelle 41,141 moreover is  
4 provided with a furling mechanism 50,150. The  
5 furling mechanism 50,150 comprises a first boom  
6 51,151 and a second boom 52,152. The booms  
7 51,151;52,152 and their respective ends thereof are  
8 provided with tail fins 53,153;54,154.

9  
10 The furling mechanism 50,150 has two functions. The  
11 first function is to keep the rotational axis 26 of  
12 the rotor 20,120 essentially parallel to the  
13 momentaneous direction of the airflow. In Fig 1 the  
14 airflow is schematically indicated by means of  
15 arrows 15. The second function of the furling  
16 device 50,150 is to rotate the rotor 20,120 out of  
17 the wind when the wind velocity exceeds the output  
18 power requirements of the wind turbine or endangers  
19 the system's integrity, in order to protect the wind  
20 turbine 10,110 against unacceptably high loads.  
21 The construction and the working of the furling  
22 mechanism will be clarified below, with reference to  
23 Figs 2A, 2B, 3, 4, 5A and 5B.

24  
25 It is to be understood that whilst the remaining  
26 description relates to the embodiment of Fig 1A, the  
27 description applies equally to the embodiment of Fig  
28 1B.

29  
30 As shown in Fig 1, the radial aerofoil 21 is  
31 attached to and encircles the turbine blades 30.  
32 The radial aerofoil 21 will create a slight venturi

1 effect near the blade tips where the resulting  
2 increase in air velocity has the largest effect on  
3 the power output of the turbine. This increases the  
4 overall efficiency of the turbine 10, which  
5 compensates for the slight increase in weight and  
6 aerodynamic drag caused by the addition of the  
7 aerofoil 21. The aerofoil will also create a more  
8 laminar flow along the rotor blades. This is  
9 important since the airflow on a roof typically is  
10 turbulent. A further advantage is the fact that the  
11 presence of the radial aerofoil 21 will increase the  
12 mechanical strength of the rotor 20, allowing more  
13 efficient aerofoil section to each blade 30. A  
14 further advantage is the fact that the presence of  
15 the radial aerofoil 21 results in a reduction in the  
16 acoustic emissions (noise) from the spinning turbine  
17 rotor blades 30 due to the fact that noise including  
18 aerodynamic vortex shedding is eliminated or  
19 reduced. The presence of the radial aerofoil 21  
20 also helps to reduce the effect of turbulent airflow  
21 through the rotor plane, and in this way also  
22 assists in reducing the acoustic emissions.

23  
24 In Fig 1 it can be seen that the design of the blade  
25 30 is such that the outer tips 31 of the blade 30  
26 are in essence perpendicular to the rotational axis  
27 26.

28  
29 The outer tips 31 of the blade are connected near  
30 the leading edge 22 of the aerofoil 21. The number  
31 of blades 30 may be varied. The aerofoil 21 may be

1 positioned to extend in an upstream or downstream  
2 orientation with respect to the blades 30.

3

4 In Fig 2 a top view is shown of the rotor 20 and the  
5 furling device 50 of the wind turbine 10 according  
6 to Fig 1. The furling device 50 comprises booms  
7 51,52 each provided with a tail fin 53,54 at the end  
8 thereof. The airflow 15 will exert a certain  
9 pressure on the tail fins 53,54. The tail fins will  
10 balance and stabilise the position of the rotor 20  
11 with respect to the direction of the airflow 15.  
12 When the direction of the airflow 15 changes the  
13 resulting pressure on the tail fins 53,54 will also  
14 change. The resulting force will cause the rotor 20  
15 to rotate in order to maintain the direction of the  
16 airflow 15 in essence in line with the rotational  
17 axis 26 of the rotor 20. During normal furling the  
18 presence of the aerofoil 21 will reduce vibrations  
19 caused by imbalanced blade tip vortex shedding.  
20 This is achieved in that the aerofoil will act to  
21 divert the airflow from the blade tips during  
22 furling.

23

24 The furling device 50 according to the present  
25 invention not only maintains an optimal angle  
26 between the rotor 20 and the airflow 15, but in  
27 addition acts to protect the turbine 20 during  
28 excessively high wind loadings. The furling device  
29 50 is designed to rotate the turbine (rotor) 20,  
30 about axis 42, out of the airflow when the wind  
31 velocity exceeds the output power requirements of  
32 the turbine or when the wind loading compromises the

1 integrity of the rotor 20 or other turbine  
2 components. As shown in Fig 2, the tail fins 53,54  
3 form a wedge pointing into, out of substantially  
4 parallel to the wind. Excessive wind loadings will  
5 make the tail fins 53,54 move and/or rotate with  
6 respect to the nacelle 41. Preferably one of the  
7 fins has no travel or limited travel, causing the  
8 rotor 20 to furl (or rotate) about axis 42 as the  
9 second fin continues to rotate under high airflow  
10 velocities. It means that the furling mechanism 50  
11 according to the present invention under moderate  
12 wind velocity will keep the rotor 20 in a stable  
13 condition and at a preferred angle with respect to  
14 the airflow 15. Only after exceeding a  
15 predetermined wind velocity, the same furling device  
16 50 will cause the rotor 20 to rotate out of the wind  
17 in order to protect the integrity thereof.

18  
19 The construction of the furling device 50 according  
20 to the present invention causes the furling device  
21 to act non-linearly in relation to the wind  
22 velocity. The furling device 50 limits the  
23 turbine's susceptibility to gusts and turbulence.  
24 Light gusts will not be able to move the rotor out  
25 of the wind. The safety function of the furling  
26 device 50 will only operate in high wind situations  
27 in order to protect the turbine and a respective  
28 generator.

29  
30 As shown in Fig 2 the booms 51 and 52 extend from  
31 the nacelle to the tail fins, in the downwind  
32 direction of the rotor 20. The respective tail fins

1 53 and 54 are positioned essentially in line with  
2 the exterior dimensions of the rotor 20. The  
3 construction of the furling device 50 according to  
4 the present invention enables a compact construction  
5 and does not necessitate free space behind the  
6 nacelle 41. That means that the design of this  
7 furling system allows the overall length of the  
8 turbine to be considerably reduced when compared to  
9 existing wind turbines.

10

11 In Figs 3 and 4 the first embodiment of the boom 51  
12 and respective tail fin 53 is shown. The arrows  
13 indicate the movement of the boom 51 with respect to  
14 the nacelle 41. The angle between the rotation axis  
15 26 of the rotor (not shown) and the tail fin 53 is  
16 changed by use of a hinge 60 located at the base of  
17 the boom 51. As shown in Fig 4, the boom 51 is held  
18 at a fixed angle to axis 26 by a coil spring 61.  
19 When the wind loading on the fin 53 is sufficiently  
20 large, the boom 51 and the fin 53 rotate against the  
21 retaining force of the coil spring 61, causing an  
22 out of balance aerodynamic loading on the rotor 20.  
23 This out of balance force will cause the nacelle to  
24 rotate about its mounting axis 42 (see Fig 1). It  
25 should be noted that the coil spring 61 as shown in  
26 Fig 4 is simply for explanatory purposes and any  
27 type of spring could be used in the hinge 60.

28

29 In Fig 5A an alternative embodiment is shown wherein  
30 the rotation of the furling fin takes place about a  
31 hinge 70 located at the outer tip of the boom. In a  
32 further preferred embodiment, the hinge is a sprung

1 hinge 170 as shown in Fig 5B. As shown in Fig 5  
2 clockwise rotation of the fin 53 at the hinge 70 is  
3 limited by an end stop 71. The anti-clockwise  
4 rotation of the fin 53 is restrained by the reaction  
5 of a coil spring (not shown) or the sprung hinge  
6 170. When the speed of the airflow 15 increases to  
7 a level at which furling is required, the retaining  
8 force of the spring in the hinge 70 or the sprung  
9 hinge 170 is overcome and the fin 53 (or in the  
10 alternative preferred embodiment the fin 154) will  
11 rotate. This causes an out of balance aerodynamic  
12 loading on the rotor. This out of balance force  
13 will again cause the nacelle to rotate about its  
14 mounting axis 42, until the aerodynamic forces on  
15 the turbine are in equilibrium. The non-linear  
16 furling mechanism 50 according to the present  
17 invention will keep the turbine windward and stable  
18 until the wind velocity compromises the systems  
19 safety and the turbine is progressively yawed from  
20 the wind. The furling device 50 therefore reduces  
21 constant yawing of the turbine during gusts, which  
22 would otherwise create unwanted oscillations and  
23 turbine blade noise.

24

25 It is to be understood that whilst there is  
26 described embodiments whereby the hinging feature is  
27 located at extreme ends of the boom 51,52, the hinge  
28 could be provided at any point along the boom 51,52.

29

30 Additionally or alternatively, the fin 53 or 54 can  
31 be arranged to fold along their horizontal axis thus  
32 causing the imbalance in that way.

1  
2 The actual furling angle necessary to protect the  
3 wind turbine can be limited because of the presence  
4 of the aerofoil 21. A certain furling of the rotor  
5 20 will result in aerodynamic stalling along the  
6 foil 21 and/or blades 30. As soon as the stalling  
7 starts, the power of the wind flow 15 on the rotor  
8 20 will drop.

9  
10 In Fig 6 a schematic overview of a wind turbine  
11 heating system is shown. The wind turbine heating  
12 system comprises a first water reservoir 118. In  
13 the water reservoir one or more electric heating  
14 elements 114 are provided. The electrical heating  
15 elements 114 are coupled with the wind turbine 10  
16 via a control unit 116. The electrical current  
17 generated by the wind turbine 10 will be directed to  
18 the electrical heating elements 114 in order to heat  
19 up the water contained in reservoir 118. While the  
20 efficiency of the heat transfer for electric heating  
21 elements may be considered to be near 100%,  
22 operating an element at a lower power input than  
23 that for which it was designed results in a lower  
24 element temperature. The nature of wind power is  
25 such that the power output will usually be  
26 considerably below the overall rated power of the  
27 heating system. As such, it is necessary to use  
28 heating elements 114 with an appropriate power  
29 rating.

30  
31 The water reservoir 118 is designed to store warm  
32 water, prior to use. The reservoir 118 may be a

1 cylinder manufactured from copper alloy but any  
2 shape of cylinder or any material may be used such  
3 as enamelled steels and plastics. Steel cylinders  
4 are better suited to higher pressure applications,  
5 while copper is attractive due to its inherent  
6 corrosion resistance and the associated long  
7 service-life. For vented systems and their  
8 associated lower cylinder pressure, copper cylinders  
9 are well suited.

10

11 When, using the system according to Fig 6, all of  
12 the water in the reservoir 118 has been heated to  
13 the maximum allowable temperature, the control unit  
14 116 will no longer allow the heating elements 114 to  
15 dissipate power into the water reservoir 118. That  
16 means that the power generated by the wind turbine  
17 has to be "dumped" elsewhere (dump element). As  
18 long as the wind turbine 10 is generating  
19 electricity, it is essential that there is a means  
20 of dissipating the electrical energy at all times.

21

22 This dump element is activated by the electronic  
23 control system turning the said dump element "on"  
24 when the power available from the wind exceeds the  
25 power take-off due to a loss or reduction of  
26 electrical load caused by the switching off,  
27 reduction or separation of the said electrical load.  
28 The said element is triggered by an increased rotor  
29 speed above a defined "dump on" rotor speed caused  
30 by the imbalance of wind turbine rotor torque and  
31 wind turbine generator torque. The said wind  
32 turbine rotor torque is dependent on wind speed and



1 the said wind turbine generator torque is dependent  
2 on the electrical load. The said dump element  
3 serves to increase the wind turbine generator torque  
4 above the wind turbine rotor torque reducing the  
5 wind turbine rotor speed until it approaches or  
6 reaches a stall. The generator torque is then  
7 reduced by releasing the dump load when the wind  
8 turbine rotor speed falls below a defined "dump off"  
9 rotor speed. The said "dump on" and "dump off"  
10 rotor speeds are defined proportionally to the power  
11 take-off and electrical load.

12  
13 Water heated in a hot water reservoir 118 with  
14 elements 114 will tend to form stratified layers.  
15 The temperature within each layer will not vary much  
16 as heat will be spread by conduction and convection.  
17 A high temperature gradient exists between layers.  
18 This phenomenon would be useful in a situation where  
19 several heating elements are used, as the top layer  
20 could be heated up, and then left undisturbed by the  
21 convection below it as lower layers were  
22 subsequently heated.

23  
24 It should be noted that the heating element design  
25 described herein could be used with or without a  
26 mains connection in tandem. The mains connection  
27 would allow the immersion heating element (or a  
28 dedicated mains element) to provide energy when none  
29 is available from the wind turbine.

30  
31 With respect to the efficiency of the wind turbine,  
32 the power extracted from the wind by the rotor

1     should be limited to approximately 60% (59,6%).  
2     Because of the fact that the wind turbine according  
3     to the present invention can be operated in  
4     turbulent airflows, the efficiency of the wind  
5     turbine according to the present invention can be  
6     improved by adding a new control system.

7  
8     Fig 7 schematically shows the working of the control  
9     system according to the present invention. First,  
10    the load on the wind turbine is near a predetermined  
11    starting level (L0). Multiple measurements of rotor  
12    speed are made after defined time periods. These  
13    measurements are used to calculate the first, second  
14    and third order values to the said increase or  
15    decrease on power take-off. The said first, second  
16    and third order values determining a change in the  
17    existing power take-off and the amount of power  
18    taken from the wind turbine is again adjusted.

19  
20    The method of controlling the level of power taken  
21    from a wind turbine comprises the following steps  
22    taken by the control means:

- 23       (a) increasing or decreasing the power take-off
- 24           from the wind turbine by a small amount;
- 25       (b) temporarily setting the level of power take
- 26           -off;
- 27       (c) after a predetermined time period, taking a
- 28           number of measurements of the rotor speed;
- 29       (d) calculating the first, second and third
- 30           order values, namely speed,
- 31           acceleration/deceleration and rate of change
- 32           of acceleration/deceleration respectively,

1           to the said increase or decrease in power  
2           take-off;

3       (e)   adjusting the power taken from the wind  
4           turbine in response to the calculation.

5

6       Steps (b) to (e) are then repeated continuously.

7

8       The control means uses the following logic to  
9       determine the adjustment:

- 10      (a)   IF: there is a positive second order rotor  
11           speed response (acceleration) and an  
12           increasing rate of said acceleration  
13           (positive third order response) of the rotor  
14           speed; THEN: the control means causes an  
15           increase in the power take-off; OR
- 16      (b)   IF: there is a positive second order rotor  
17           speed response (acceleration) and decreasing  
18           rate of said acceleration (negative third  
19           order response) of the rotor speed; THEN:  
20           the control means causes an increase or  
21           alternatively no change in the power take-  
22           off; OR
- 23      (c)   IF: there is a negative second order rotor  
24           speed response (deceleration) and increasing  
25           rate of said deceleration (positive third  
26           order response) of the rotor speed; THEN:  
27           the control means causes a reduction in the  
28           power take-off; OR
- 29      (d)   IF: there is a negative second order rotor  
30           speed response (deceleration) and decreasing  
31           rate of said deceleration (negative third  
32           order response) of the rotor speed; THEN:

1           the control means causes an increase or  
2           alternatively no change in the power take-  
3           off.

4  
5       The control means repeats the above steps to  
6       continue adjusting the power take-off to ensure that  
7       the power take-off is always maximised to the power  
8       available to the wind turbine, or yield, which is  
9       dependent on the local wind speed at the rotor  
10      plane.

11  
12      Because of the fact that the wind velocity on the  
13      rotor will be continuously varying, the time  
14      interval for increasing and decreasing the amount of  
15      load on the wind turbine will typically be in the  
16      ranges of milliseconds to tens of seconds.

17  
18      The efficiency of the wind turbine heating system  
19      can be further increased when using an alternative  
20      water reservoir 128 as shown in Fig 8. The water  
21      reservoir 128 is provided with an electrical heating  
22      element 124. The heating element 124 is covered,  
23      over a substantive length thereof, by means of an  
24      enclosing tube 125. The bottom end 126 of the tube  
25      125 is open. This enables water to flow in between  
26      the exterior of the heating device 124 and the  
27      interior of the tube 125. As soon as current passes  
28      through the element 124 the electrical energy will  
29      be converted into heat energy and this heat energy  
30      is then transferred to the water. The water film  
31      directly enclosing the heating element 124 will be  
32      heated and, due to natural convection, will flow

1 towards the top of the reservoir 128 and is  
2 prevented from diffusing radially into the reservoir  
3 128. Because of the presence of the tube 125 the  
4 heated water is directed towards a warm water zone  
5 130 in a top part of the reservoir 128. The heat  
6 generated by the heating element 124 therefore is  
7 concentrated in the top part of the reservoir 128  
8 and is prevented from diffusing radially into the  
9 reservoir 128. This will limit the time necessary  
10 to heat up water to a preferred temperature thus  
11 reducing the energy consumption of thereof.

12  
13 As soon as the power generated by the wind turbine  
14 is increased, the amount of heat transferred to the  
15 water in the reservoir 128 is also increased. This  
16 means that the flow of heated water towards the top  
17 part of the reservoir 128 will increase, resulting  
18 in mixing the thermally stratified layers, and in an  
19 enlarged warm water area 130. This effect is shown  
20 in Fig 9. Because of the construction of the  
21 reservoir 128, power no longer has to be "dumped".  
22 The use of the reservoir 128 is especially suitable  
23 for a wind turbine, because of the fact that the  
24 nature of wind power is such that the power output  
25 will usually fluctuate and moreover will be below  
26 the overall rated power of the heating system.

27

28 During normal operation of a wind turbine according  
29 to the invention, vibrations are caused by harmonic  
30 resonance within the turbine, tower and mounting  
31 structure. These come from blade imbalances, due to  
32 deformation during operation, aerodynamically

1 induced vibrations or mechanically induced  
2 vibrations in the rotor, generator or other turbine  
3 components. Eliminating resonance in micro-wind  
4 turbines is especially difficult as they operate  
5 through a wide range of turbine tip-speeds. The  
6 design described below reduces the operating  
7 vibrations by controlling the turbine tip-speeds so  
8 that they remain outside natural resonant  
9 frequencies, and through novel vibration absorption  
10 measures.

11  
12 Mounting a horizontal axis wind turbine on a  
13 building structure requires the damping of critical  
14 frequencies and the moving of harmonics beyond the  
15 system operating frequencies. The damping system on  
16 the rooftop wind turbine is integrated into the  
17 design of the mounting means and nacelle of the  
18 turbine. These vibration absorbing systems work  
19 together to create a silent running rooftop turbine.

20  
21 The novel wind turbine mounting bracket uses a  
22 sandwich construction of viscoelastic materials and  
23 structural materials.

24  
25 The mounting means tower contains an innovative  
26 core, typically of rubber, which has some sections  
27 which have a reduced cross-sectional area and are  
28 not in contact with the mounting means' inner  
29 surface and some sections which are. This serves to  
30 absorb vibrations in the mounting means through the  
31 energy dissipated in the rubber core before they  
32 reach the mounting bracket. The rubber core also

1 acts to force the system's resonant frequency above  
2 the turbine driving frequency.

3  
4 In Fig 10 a possible embodiment of the interior of  
5 the mounting means is shown, in cross-section. In  
6 this embodiment, the mounting means is tubular in  
7 cross-section. The mounting means 40 comprises a  
8 hollow core wherein a cylindrical core element 90 is  
9 present. The core element 90 in the middle thereof  
10 is provided with a hollow section 91 in order to  
11 allow elements such as a power line to be guided  
12 through the interior of the core element 90. The  
13 core element 90 is provided with sections 92 with an  
14 exterior diameter corresponding substantially to  
15 the interior diameter of the mounting means 40.  
16 These sections alternate with sections 93 that have  
17 a reduced diameter and are not in contact with the  
18 mounting means' 40 inner radial surface. The  
19 sandwich mounting bracket together with the mounting  
20 means core design suppresses vibrations in the  
21 system. The main sources for those vibrations are  
22 vibrations transmitted from the wind turbine to the  
23 building, and the aerodynamic turbulence around  
24 obstacles, which decreases power output but more  
25 importantly shortens the working life of the wind  
26 turbine.

27  
28 In Fig 11 an alternative embodiment of the interior  
29 of the mounting means is shown, in cross-section.  
30 The hollow core of the mounting means 40 is provided  
31 with a core element 94. The core element 94 in the  
32 middle thereof is provided with a hollow section 91.

1 The core element 94 is provided with sections 92  
2 with an exterior diameter corresponding  
3 substantially to the interior diameter of the  
4 mounting means 40. These sections alternate with  
5 sections 93 that have a reduced diameter and are not  
6 in contact with the mounting means' 40 inner radial  
7 surface. When comparing Figs 10 and 11 it will be  
8 clear that the shape of the recesses in respective  
9 core elements 90 and 94 differs. It should be noted  
10 that Figs 10 and 11 are for illustration purposes  
11 only. Alternative embodiments for the core elements  
12 are also possible.

13  
14 Fig 12 shows a further embodiment of the interior of  
15 the mounting means 40. As shown in Fig 12, the  
16 interior of the mounting means 40 comprises several  
17 core elements 95, which are inserted in the mounting  
18 means wherein a first element 95 abuts an adjacent  
19 element 95. In the example of Fig 12 the shape of  
20 the recesses in the respective elements 95 again  
21 differs from the embodiments according to Fig 10 and  
22 Fig 11.

23  
24 In a wind turbine noise comes from two areas,  
25 aerodynamic sources and mechanical sources.  
26 Aerodynamic noise is radiated from the blades,  
27 originating due to the interaction of the blade  
28 surfaces with turbulence and natural atmospheric or  
29 viscous flow in the boundary layer around the  
30 blades. Mechanical noise is due to the relative  
31 motion of mechanical components and the dynamic



1 response among them. This effect may be magnified  
2 if the nacelle, rotor and tower transmit the  
3 mechanical noise and radiate it, acting as a  
4 loudspeaker. Two types of noise problem exist: air  
5 borne noise which is noise which is transmitted  
6 directly from the component surface or interior into  
7 the air, and structure borne noise which is  
8 transmitted through the structure before being  
9 radiated by another component.

10

11 The turbine mounting and mounting means are designed  
12 to push the resonant frequency of the whole  
13 structure out-with the operation vibration  
14 frequencies caused by blade unbalances, aerodynamic  
15 induced vibrations, mechanical induced vibrations  
16 and deformations. The mounting contains a damping  
17 system which eliminates vibrations.

18

19 As shown in Fig 13, the wind turbine 10 can form  
20 part of a wind turbine system 200 which can be  
21 connected to a stand alone or grid-tie inverter 201  
22 for connection to local power infrastructure, or to  
23 a local or embedded grid connection 202. The system  
24 200 can also be provided with a rectifier 203 which  
25 rectifies the power output from the wind turbine 10  
26 and feeds the rectified power to an electronic  
27 controller 204 (as described in previous  
28 embodiments) which can either "dump" excess load 205  
29 (which may be done as described above for other  
30 embodiments by way of an external resistive load) or  
31 supply power to the inverter 201. In this way the  
32 wind turbine system 200 can be utilised to feed

1 power to power infrastructure such as a local grid  
2 network or the national grid.

3

4 As shown in Fig 14, the wind turbine 10 can form  
5 part of a wind turbine system 300 which can be  
6 connected to an energy storage device 301. The  
7 storage device may be in the form of battery packs,  
8 or any other suitable form of energy storage device.  
9 The system 300 can also be provided with a rectifier  
10 303 which rectifies the power output from the wind  
11 turbine 10 and feeds the rectified power to an  
12 electronic controller 304 (which may be done as  
13 described above for other embodiments by way of an  
14 external resistive load) which can either "dump"  
15 excess load 305 (which may be done as described  
16 above for other embodiments) or supply power to the  
17 storage device 301. In this way the wind turbine  
18 system 200 can be utilised to feed power to a  
19 storage device for later use.

20

21 Modifications and improvements may be made to the  
22 foregoing without departing from the scope of the  
23 invention.

## 1 CLAIMS

2

3 1. A rotor for a wind turbine comprising a plurality  
4 of radial blades and a ring-shaped aerofoil diffuser  
5 connecting the outer tips of the blades.

6

7 2. A rotor according to claim 1, wherein the  
8 aerofoil diffuser extends downstream from the outer  
9 tips of the blades.

10

11 3. A rotor according to either preceding claim,  
12 wherein the outer tips of the blades are connected  
13 to the diffuser at or near to the leading edge of  
14 the diffuser.

15

16 4. A rotor according to any preceding claim, wherein  
17 the aerofoil diffuser tapers outwards from the outer  
18 tips of the blades to form a substantially frusto-  
19 conical diffuser.

20

21 the rotational axis of the frusto-conical diffuser  
22 is substantially aligned to the rotational axis of  
23 the blades.

24

25 5. A rotor according to claim 1, wherein at least a  
26 portion of the aerofoil diffuser extends upstream  
27 from the outer tips of the blades.

28

29 6. A rotor according to any preceding claim, wherein  
30 the aerofoil diffuser tapers radially outwards as it  
31 extends from the upstream end to the downstream end.

32

1 7. A rotor according to any preceding claim, wherein  
2 the aerofoil diffuser is shaped such that it  
3 inhibits the partly axial and partly radial airflow  
4 from the blades, said airflow becoming  
5 circumferential when it contacts the aerofoil  
6 diffuser.

7  
8 8. A rotor according to any preceding claim, wherein  
9 the aerofoil diffuser is adapted to inhibit partly  
10 axial and partly radial airflow from the outer tips  
11 of the blades and divert said airflow to  
12 substantially circumferential airflow during normal  
13 operation.

14  
15 9. A rotor according to any preceding claim, wherein  
16 the blades are inclined at an angle relative to a  
17 transverse rotor plane perpendicular to the  
18 rotational axis of the rotor.

19  
20 10. A rotor according to claim 9, wherein the angle  
21 of inclination may vary along the length of the  
22 blade.

23  
24 11. A rotor according to claim 9 or claim 10,  
25 wherein the angle of inclination of each blade is  
26 greater at an intermediate portion of the blade than  
27 at the outer tip of the blade.

28  
29 12. A rotor according to any preceding claim,  
30 wherein the blades are substantially parallel to the  
31 transverse rotor plane at the outer tip of the  
32 blades.

1

2 13. A wind turbine comprising a rotor according to  
3 claims 1 to 12, further comprising a nacelle and a  
4 mounting means adapted to allow rotation of the  
5 turbine and rotor about a directional axis  
6 perpendicular to the rotational axis, thus allowing  
7 the turbine to be oriented in the optimum direction  
8 depending on wind conditions.

9

10 14. A wind turbine according to claim 13, further  
11 comprising a furling means adapted to rotate the  
12 rotor about the directional axis so that the  
13 rotational axis is not parallel to the direction of  
14 airflow when the airflow speed is greater than a  
15 predetermined airflow speed.

16

17 15. A wind turbine according to claim 14, wherein  
18 the furling means comprises a non-linear furling  
19 means adapted to provide no furling over a first  
20 lower range of airflow speed and a varying degree of  
21 furling over a second higher range of airflow speed.

22

23 16. A wind turbine according to claims 14 and 15,  
24 wherein the furling means comprises at least two  
25 tail fins extending downstream of the diffuser.

26

27 17. A wind turbine according to claim 16, wherein  
28 the two tail fins are provided diametrically  
29 opposite each other.

30

31 18. A wind turbine according to claim 16 or 17,  
32 wherein one of the tail fins is a moveable tail fin

1 hingedly mounted for rotation about a tangential  
2 hinge line.

3  
4 19. A wind turbine according to claim 18, wherein  
5 the moveable tail fin may be mounted on a mounting  
6 boom and the hinge line may be provided: at the  
7 connection point of the mounting boom and the  
8 nacelle, so that the mounting boom also rotates; at  
9 the connection between the mounting boom and the  
10 moveable tail fin so that only the moveable tail fin  
11 rotates; or at any point along the length of the  
12 mounting boom.

13  
14 20. A wind turbine according to claims 18 or 19,  
15 wherein the tail fin rotates about a horizontal axis  
16 under high winds resulting in a fin which folds  
17 about a horizontal axis.

18  
19 21. A wind turbine according to claims 18 to 20,  
20 wherein the moveable tail fin is rotationally biased  
21 by biasing means to an at-rest position in which the  
22 leading edge of the moveable tail fin is closer to  
23 the axis of rotation of the rotor than the trailing  
24 edge of the moveable tail fin, such that the  
25 moveable tail fin is angled at an at-rest attack  
26 angle to the axis of rotation of the rotor.

27  
28 22. A wind turbine according to claim 21, wherein  
29 the biasing means is non-linear.

30  
31 23. A wind turbine according to claim 21 or 22,  
32 wherein the biasing means is adapted to hold the

1     moveable tail fin in the at-rest position until the  
2     airflow speed reaches a predetermined speed and is  
3     further adapted such that as the airflow speed  
4     increases beyond the predetermined speed the  
5     moveable fin rotates and the attack angle decreases,  
6     resulting in unbalanced aerodynamic loading on the  
7     wind turbine, such that the wind turbine rotates  
8     about its mounting axis to a furled position.

9

10    24. A wind turbine system comprising:

11         a wind turbine driven generator and means for  
12     providing a power output.

13

14    25. A wind turbine system according to claim 24,  
15     wherein the system further comprises an electronic  
16     control system.

17

18    26. A wind turbine system according to claim 24 or  
19     25, wherein the system comprises a dump element  
20     comprising one or more energy dissipaters.

21

22    27. A wind turbine system according to claim 26,  
23     wherein the energy dissipaters are in the form of  
24     resistive elements.

25

26    28. A wind turbine system according to claims 26 or  
27     27, wherein the dump element is in the form of a  
28     liquid storage vessel having electrical heating  
29     elements therein adapted to heat liquid in said  
30     storage vessel.

31

1 29. A wind turbine system according to claim 28,  
2 wherein the control system may be adapted to supply  
3 electrical power to said one or more electrical  
4 heating elements when the power from the wind  
5 exceeds a predetermined power.  
6

7 30. A wind turbine system according to claim 28 or  
8 29, wherein the liquid storage vessel is a cold  
9 water tank and the liquid is water.  
10

11 31. A wind turbine system according to claim 28 or  
12 29, wherein the heating element is a radiator.  
13

14 32. A wind turbine system according to claim 26,  
15 wherein the dump element is activated by the  
16 electronic control system when the power available  
17 from the wind exceeds the power take-off due to a  
18 loss or reduction of electrical load caused by the  
19 switching off, reduction or separation of the said  
20 electrical load.  
21

22 33. A wind turbine system according to claim 32,  
23 wherein the dump element is activated when the rotor  
24 speed increases above a defined "dump on" rotor  
25 speed caused by the imbalance of wind turbine rotor  
26 torque and wind turbine generator torque, said wind  
27 turbine rotor torque being dependent on wind speed  
28 and the said wind turbine generator torque being  
29 dependent on the electrical load.  
30

31 34. A wind turbine system according to claim 33,  
32 wherein said dump element is adapted to increase the



1 wind turbine generator torque above the wind turbine  
2 rotor torque reducing the wind turbine rotor speed  
3 until it approaches or reaches a stall and is  
4 further adapted such that the generator torque is  
5 released when the wind turbine rotor speed falls  
6 below a defined "dump off" rotor speed, the said  
7 "dump on" and "dump off" rotor speeds being defined  
8 proportionally to the power take-off.

9

10 35. A wind turbine system according to claims 24 to  
11 34, wherein the wind turbine system is provided with  
12 a control means adapted to control the level of  
13 power taken from the wind turbine.

14

15 36. A wind turbine system according to claim 35,  
16 wherein the control system is adapted to increase or  
17 decrease the power take-off from the wind turbine by  
18 a small amount relative to the total power take-off.

19

20 37. A wind turbine system according to claims 24 to  
21 36, wherein the system comprises a wind turbine  
22 according to claims 1 to 23.

23

24 38. A wind turbine system according to claims 24 to  
25 37, wherein the power output is connected to a  
26 heating system further comprising a further liquid  
27 storage vessel,

28 one or more electrical heating elements adapted  
29 to heat liquid in said further vessel, and

30 control means adapted to control the supply of  
31 electricity generated by said generator to said one  
32 or more electrical heating elements.

1

2 38. A wind turbine system according to claim 37,  
3 wherein the further liquid storage vessel is a hot  
4 water tank and the liquid is water.

5

6 39. A wind turbine system according to claim 38,  
7 wherein the heating system comprises a plurality of  
8 electrical heating elements, and the control means  
9 is adapted to supply electrical power to a  
10 proportion of the electrical heating elements, the  
11 proportion being dependent upon the instantaneous  
12 electrical power generated by the generator.

13

14 40. A wind turbine system according to claim 39,  
15 wherein the heating element in the further liquid  
16 vessel is enclosed by means of a tube, open on the  
17 underside thereof and adapted to allow water to flow  
18 from beneath the tube towards the heating element.

19

20 41. A wind turbine system according to claim 40,  
21 wherein the tube encloses and extends over the  
22 entire length of the heating element such that the  
23 water near the heating element is heated and will  
24 flow upwards due to natural convection, the tube  
25 being adapted to enable the formation of different  
26 and separate heat zones within the further liquid  
27 storage vessel.

28

29 42. A wind turbine system according to claims 24 to  
30 41, wherein the power output is connected to a grid-  
31 tie inverter or stand alone inverter.

32

1 43. A wind turbine system according to claim 42,  
2 wherein the inverter is adapted to supply power to  
3 local or grid power infrastructure.

4

5 44. A wind turbine system according to claims 24 to  
6 43, wherein the power output is connected to an  
7 energy storage system.

8

9 45. A method of controlling the level of power taken  
10 from a wind turbine comprising the following steps  
11 taken by a control means:

- 12 (a) increasing or decreasing the power take-off  
13 from the wind turbine by a small amount;  
14 (b) temporarily setting the level of power take  
15 -off;  
16 (c) after a predetermined time period, taking a  
17 number of measurements of the rotor speed;  
18 (d) calculating the first, second and third  
19 order values, namely speed,  
20 acceleration/deceleration and rate of change  
21 of acceleration/deceleration respectively,  
22 to the said increase or decrease in power  
23 take-off;  
24 (e) adjusting the power taken from the wind  
25 turbine in response to the calculation.

26

27 46. A method according to claim 45, wherein the  
28 control means uses the following logic to  
29 determine the adjustment:

- 30 (a) IF: there is a positive second order rotor  
31 speed response (acceleration) and an  
32 increasing rate of said acceleration

1 (positive third order response) of the rotor  
2 speed; THEN: the control means causes an  
3 increase in the power take-off; OR

4 (b) IF: there is a positive second order rotor  
5 speed response (acceleration) and decreasing  
6 rate of said acceleration (negative third  
7 order response) of the rotor speed; THEN:  
8 the control means causes an increase or  
9 alternatively no change in the power take-  
10 off; OR

11 (c) IF: there is a negative second order rotor  
12 speed response (deceleration) and increasing  
13 rate of said deceleration (positive third  
14 order response) of the rotor speed; THEN:  
15 the control means causes a reduction in the  
16 power take-off; OR

17 (d) IF: there is a negative second order rotor  
18 speed response (deceleration) and decreasing  
19 rate of said deceleration (negative third  
20 order response) of the rotor speed; THEN:  
21 the control means causes an increase or  
22 alternatively no change in the power take-  
23 off.

24

25 47. A method according to claim 45 or 46, wherein  
26 the control means repeats any of the above steps to  
27 continue adjusting the power take-off to ensure that  
28 the power take-off is always maximised to the power  
29 available to the wind turbine which is dependent on  
30 the local wind speed at the rotor plane.

31

1 48. A wind turbine according to claims 13 to 23  
2 comprising means for reducing the operating  
3 vibrations caused by harmonic resonance within the  
4 turbine, tower and mounting structure.

5  
6 49. A wind turbine according to claim 48, wherein  
7 the wind turbine is provided with a nacelle damping  
8 system, adapted to at least partially isolate the  
9 vibrations in the generator and turbine from the  
10 tower.

11  
12 50. A wind turbine according to claim 48 or 49,  
13 wherein the wind turbine is provided with mounting  
14 brackets for mounting the turbine on a surface, the  
15 brackets having a sandwich construction of visco-  
16 elastic materials and structural materials.

17  
18 51. A wind turbine according to claims 48 to 50,  
19 wherein the mounting means is tubular.

20  
21 52. A wind turbine according to claim 50, wherein  
22 the tower contains one or more cores of flexible  
23 material, such as rubber, with sections with a  
24 reduced diameter, which are not in contact with the  
25 tower's inner radial surface, such that the reduced  
26 diameter sections alternate with normal sized  
27 sections, which are in contact with the tower's  
28 inner surface thus serving to absorb vibrations in  
29 the tower through the energy dissipated in the  
30 flexible core before they reach the mounting  
31 brackets.

32

1 53. A wind turbine according to claim 52, wherein  
2 the rubber core is adapted to control the system's  
3 resonant frequency out-with the turbine driving  
4 frequency by absorption of a range of vibration  
5 frequencies.

6  
7 54. A wind turbine according to claim 53, wherein  
8 the cross-sectional shape and length of each of the  
9 reduced diameter sections is altered thus "tuning"  
10 the system to remove a range of vibration  
11 frequencies from the mounting structure.

12  
13 55. A wind turbine according to claims 48 to 54,  
14 wherein the sandwich mounting brackets compliment  
15 the mounting means core design and suppress  
16 vibrations that come from the nacelle.

17  
18 56. A wind turbine according to claim 55, wherein  
19 the nacelle supports the generator through bushes  
20 designed to eliminate vibration frequencies.

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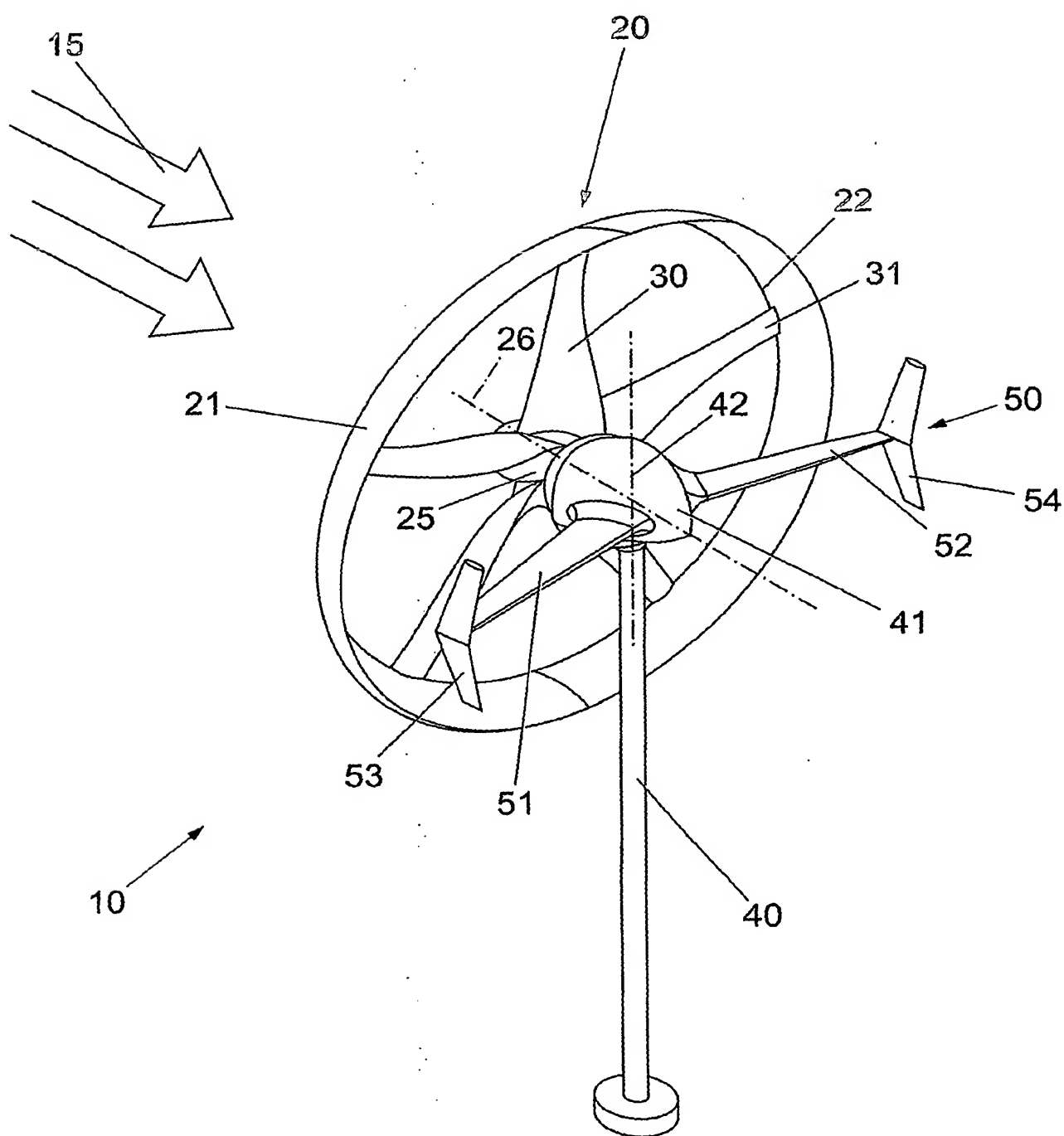


Fig. 1a

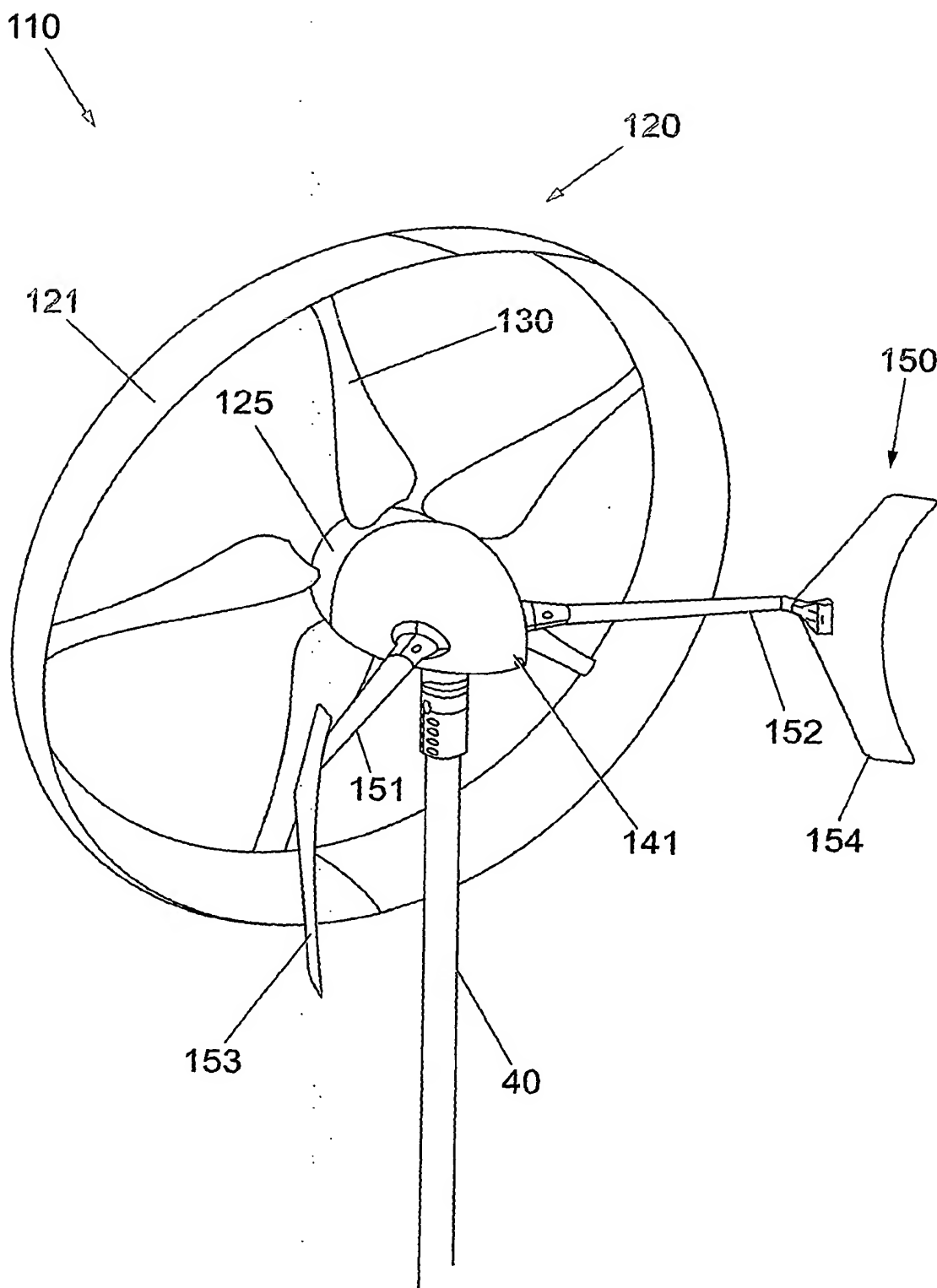
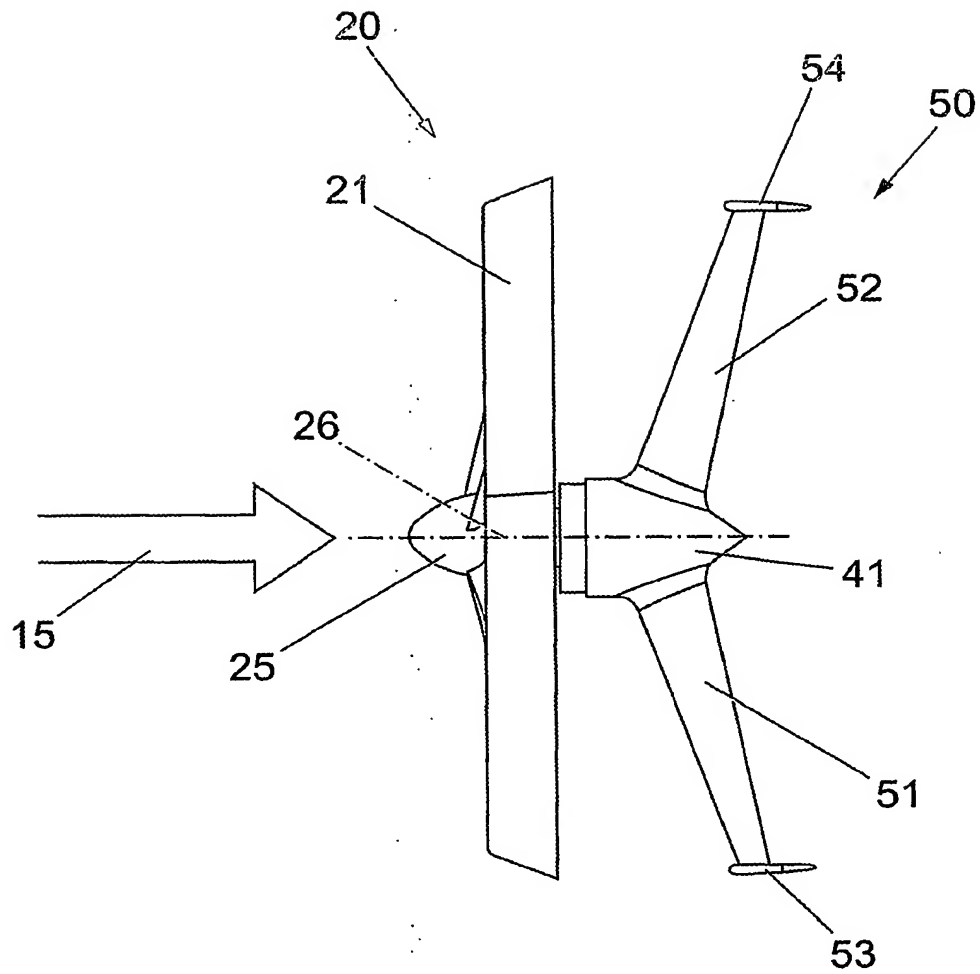


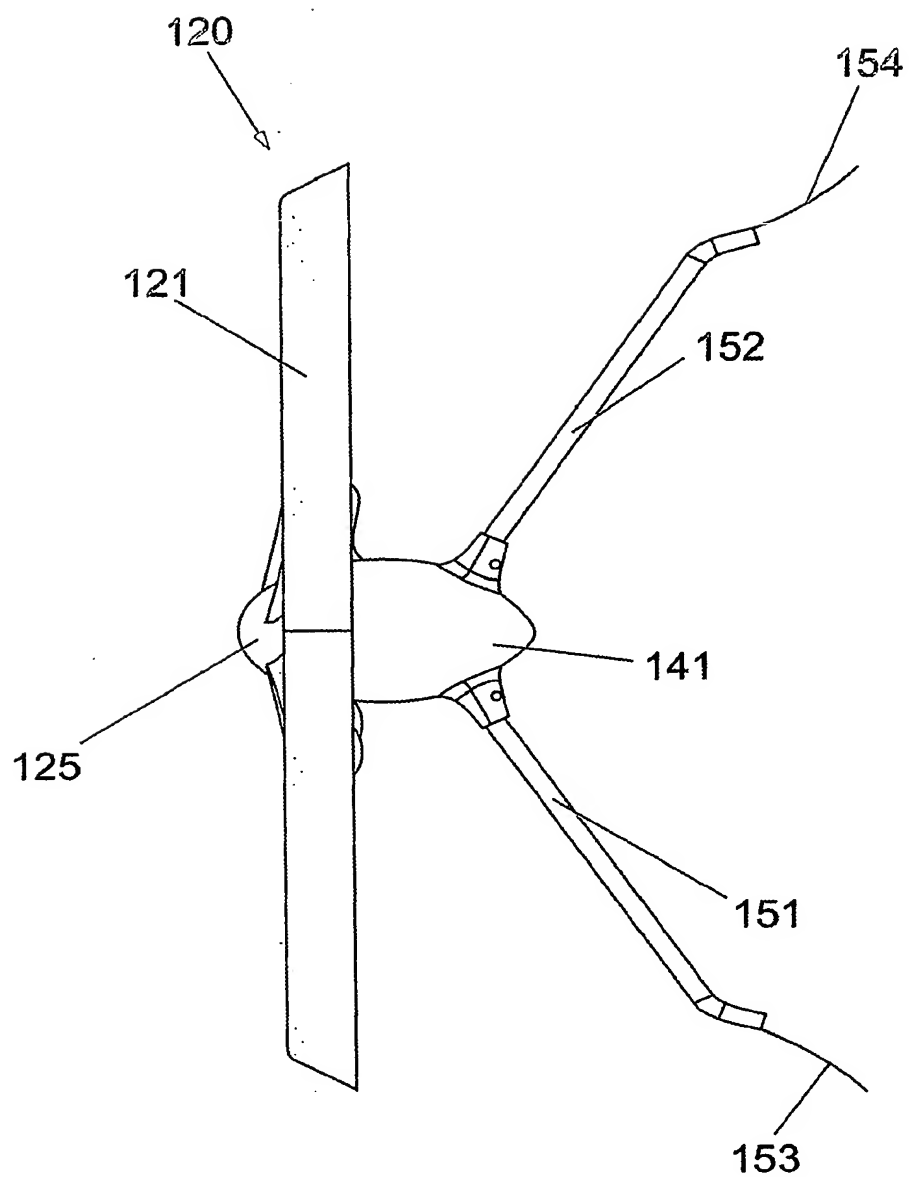
Fig. 1b



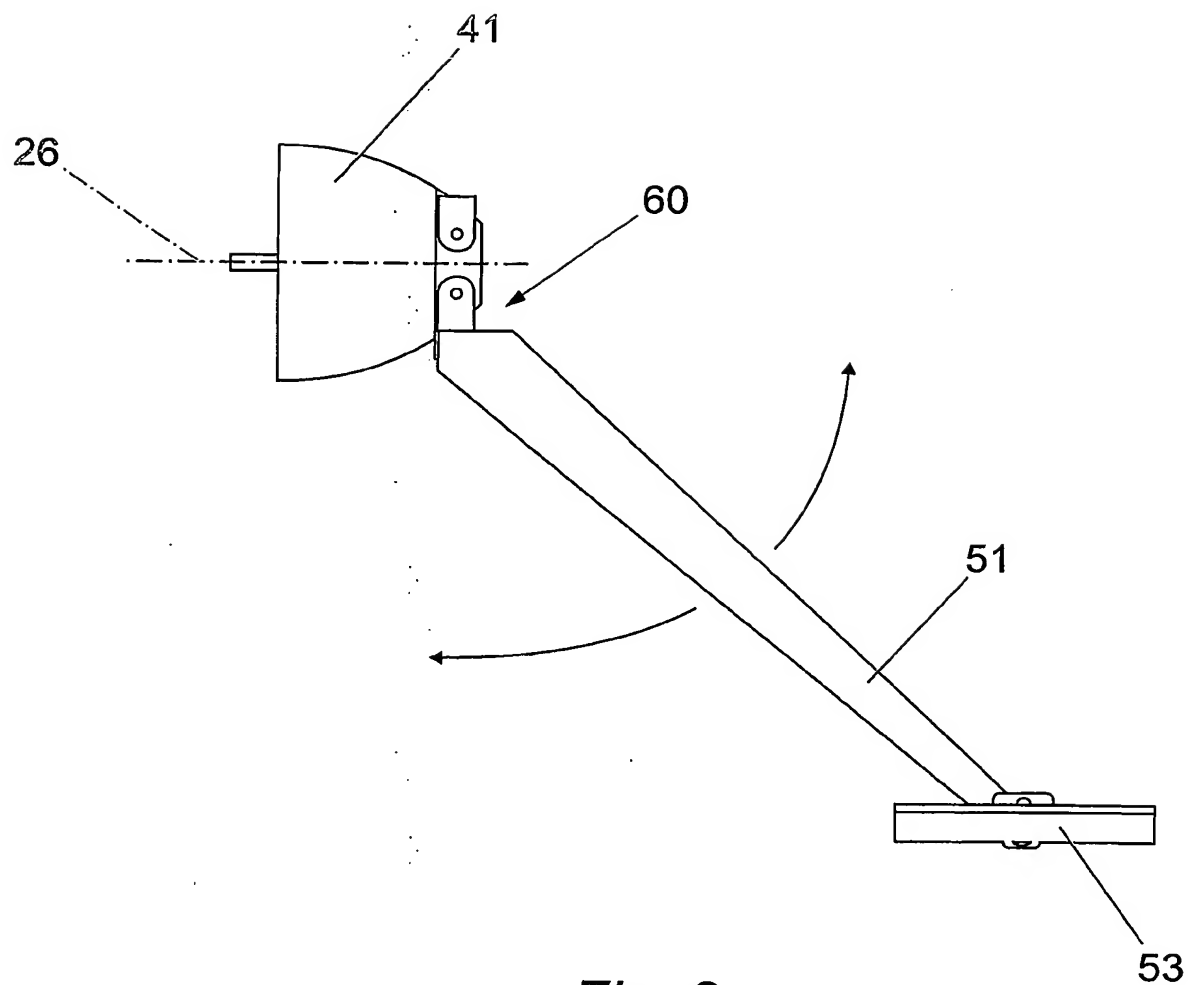
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*Fig. 2a*

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*Fig. 2b*

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*Fig. 3*

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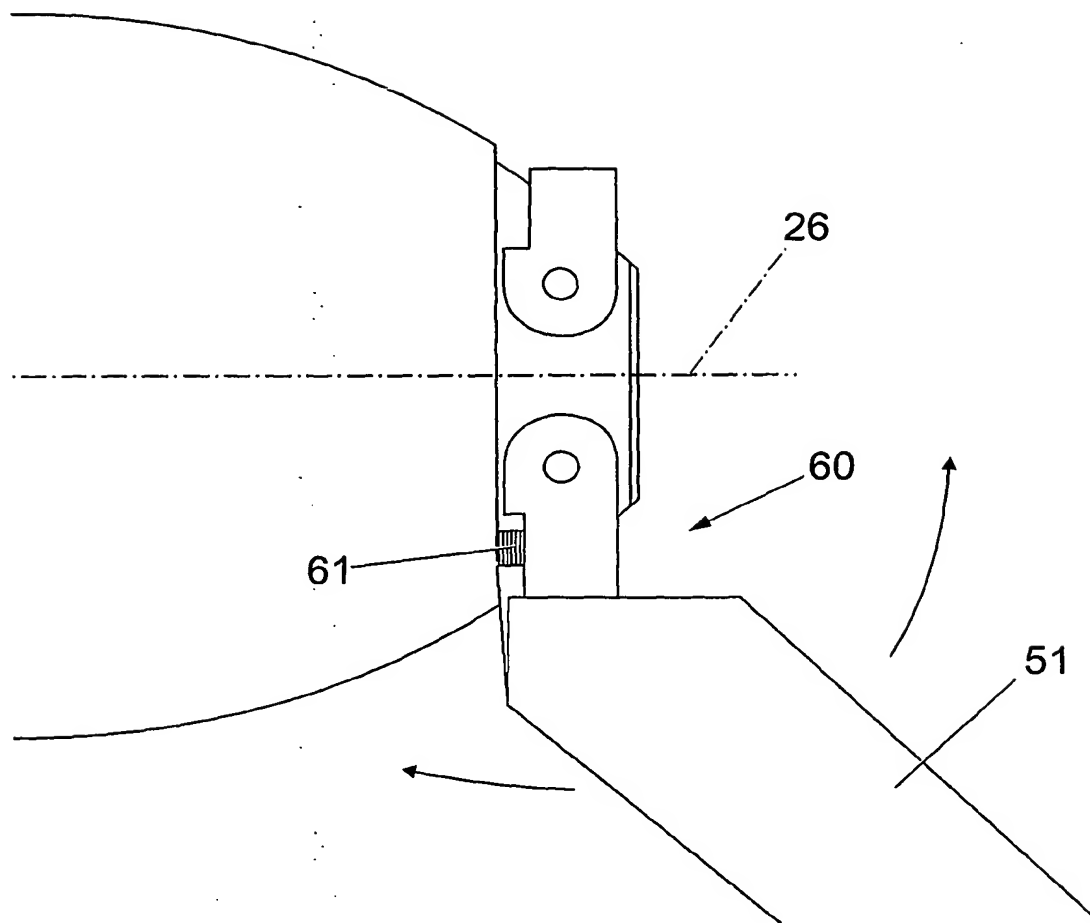
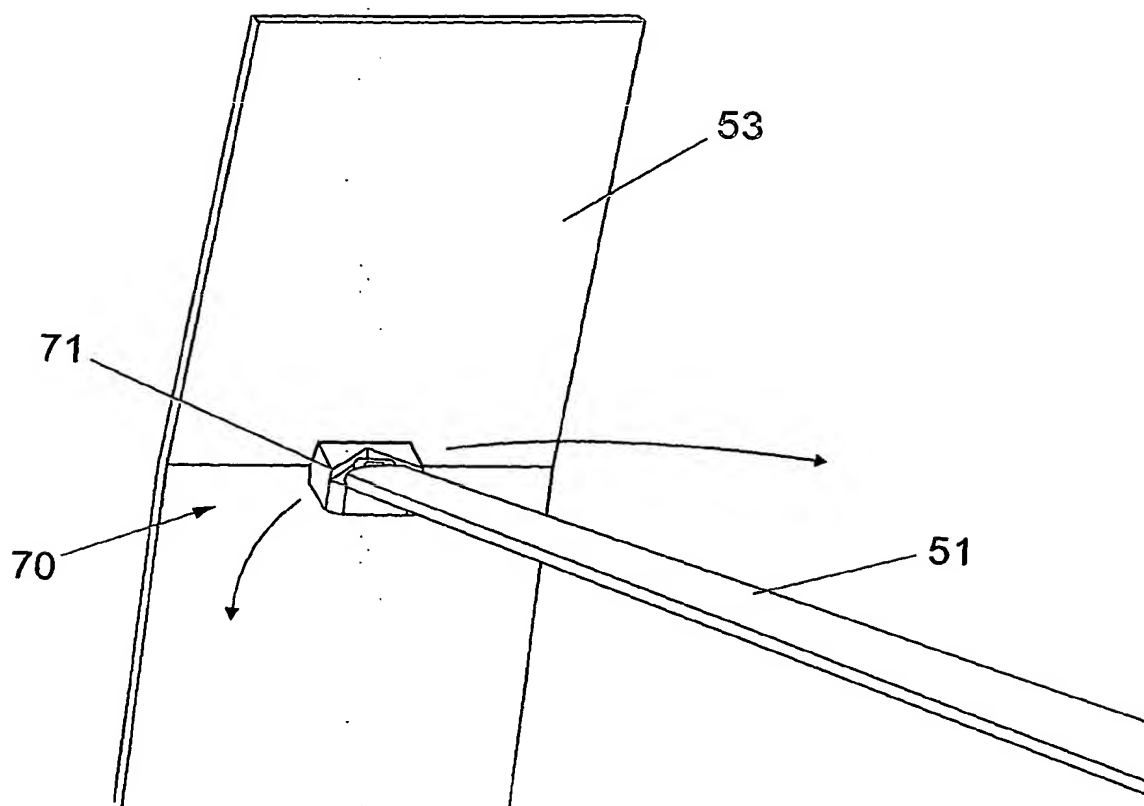
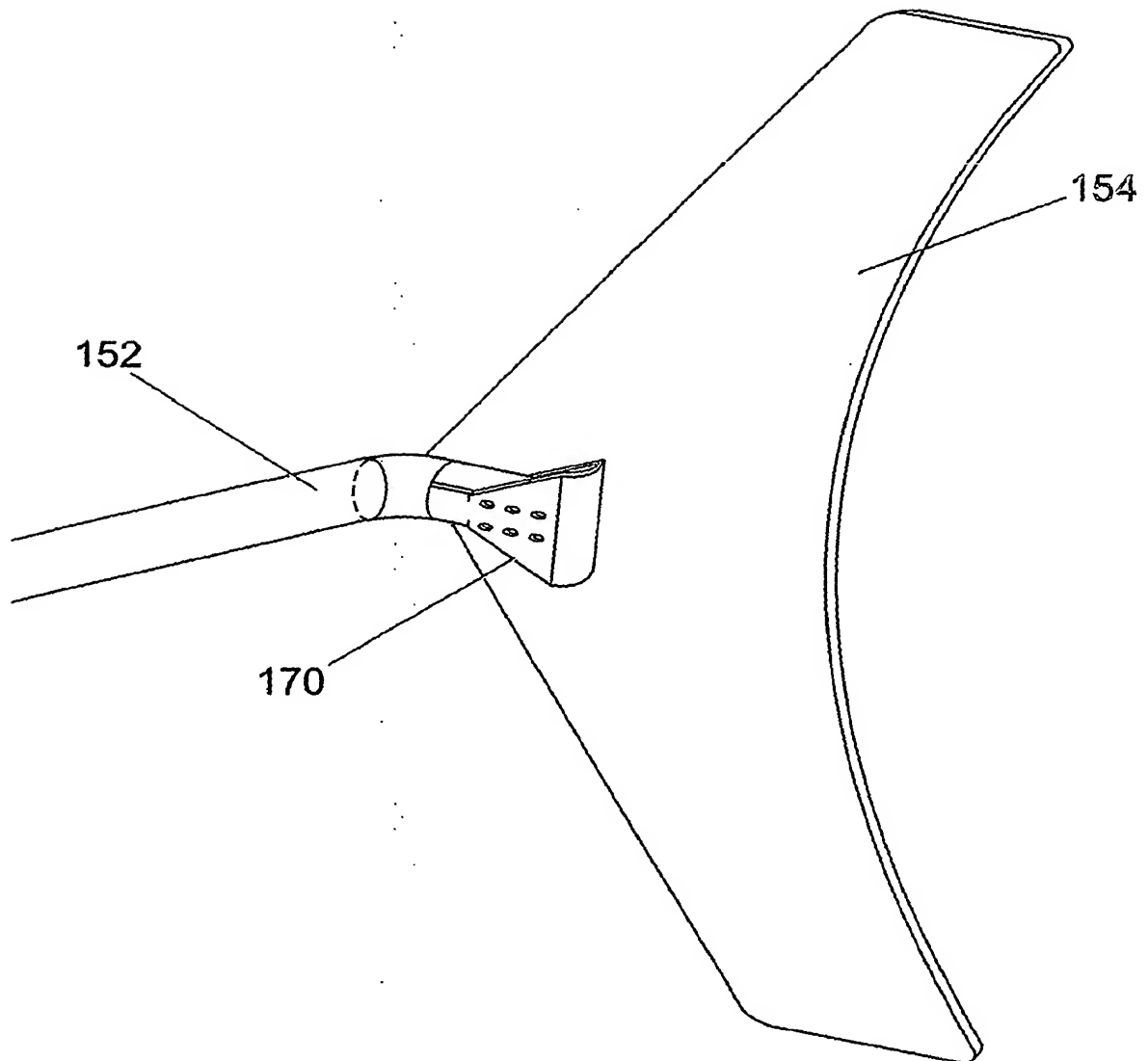


Fig. 4

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*Fig. 5a*

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*Fig. 5b*

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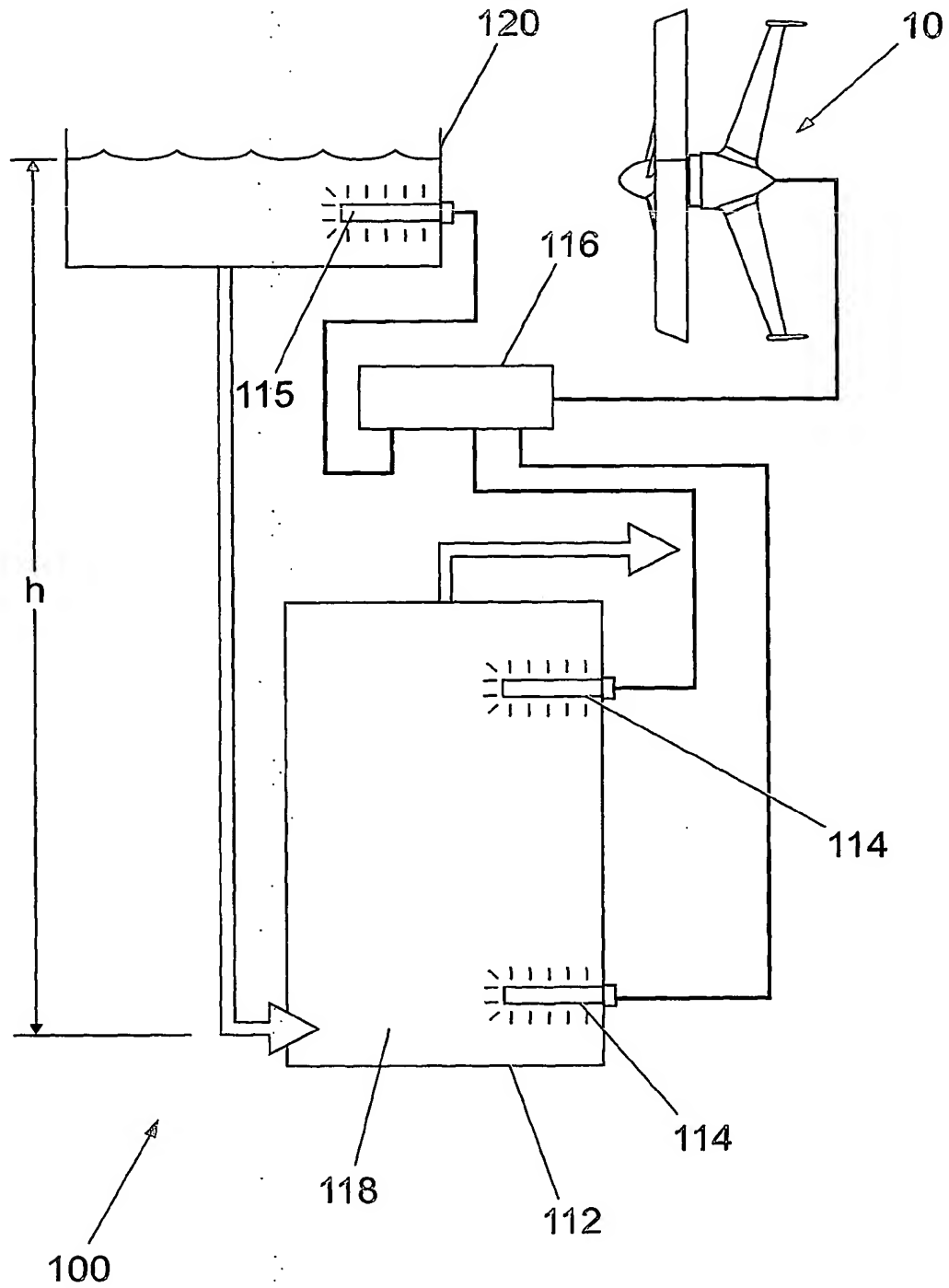
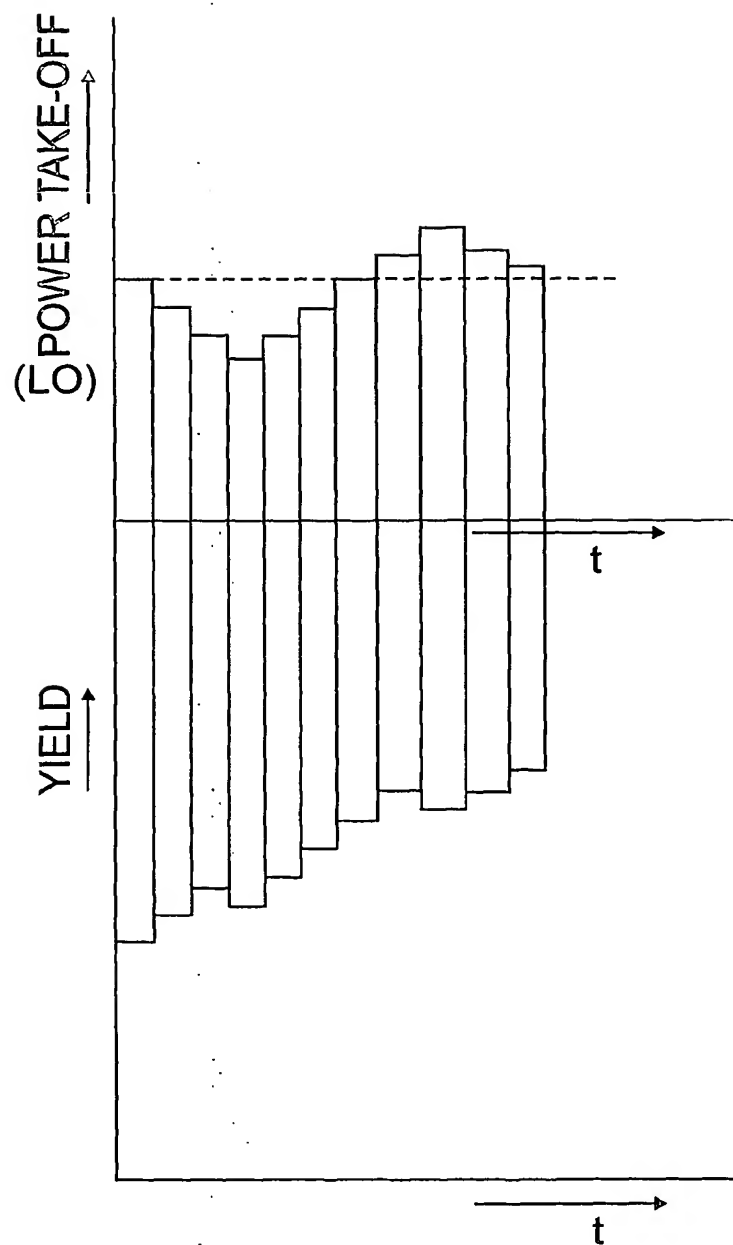


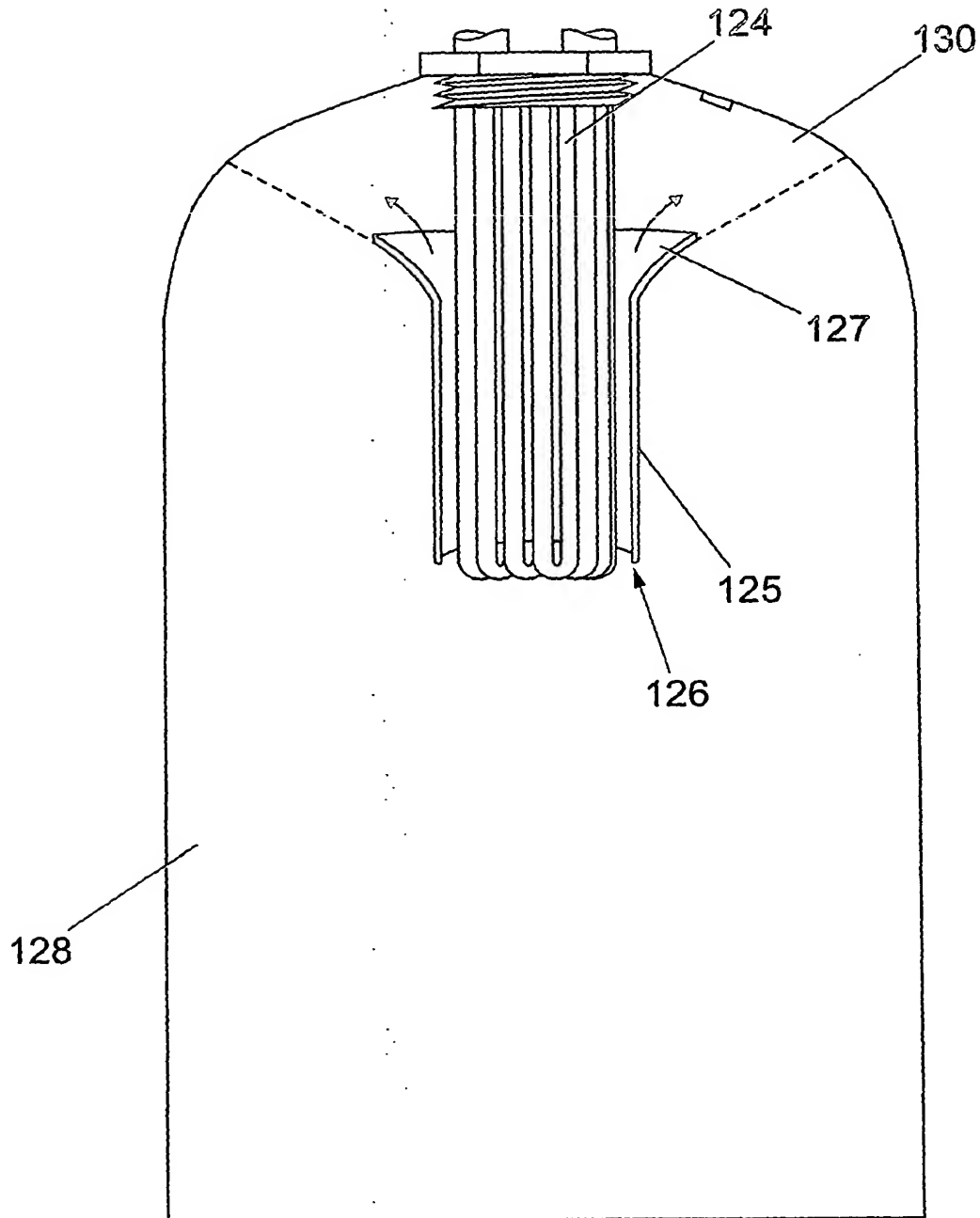
Fig. 6

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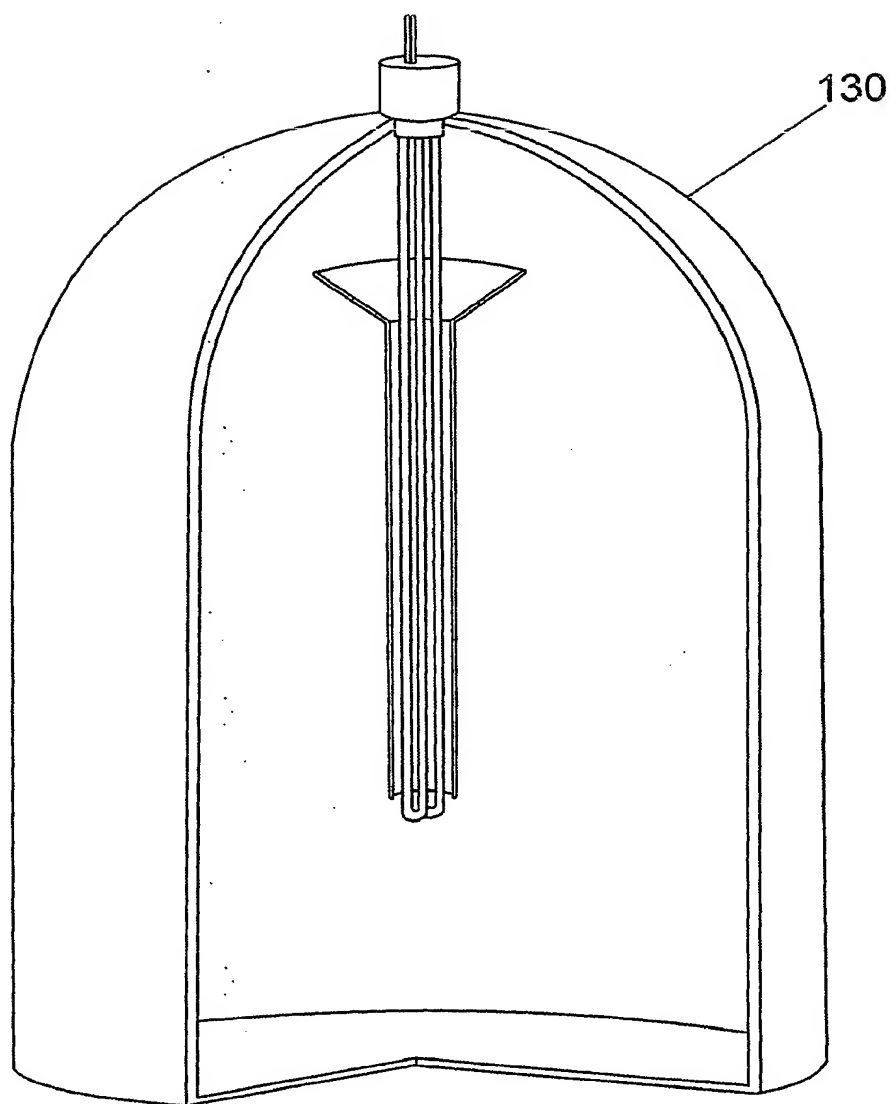
*Fig. 7*



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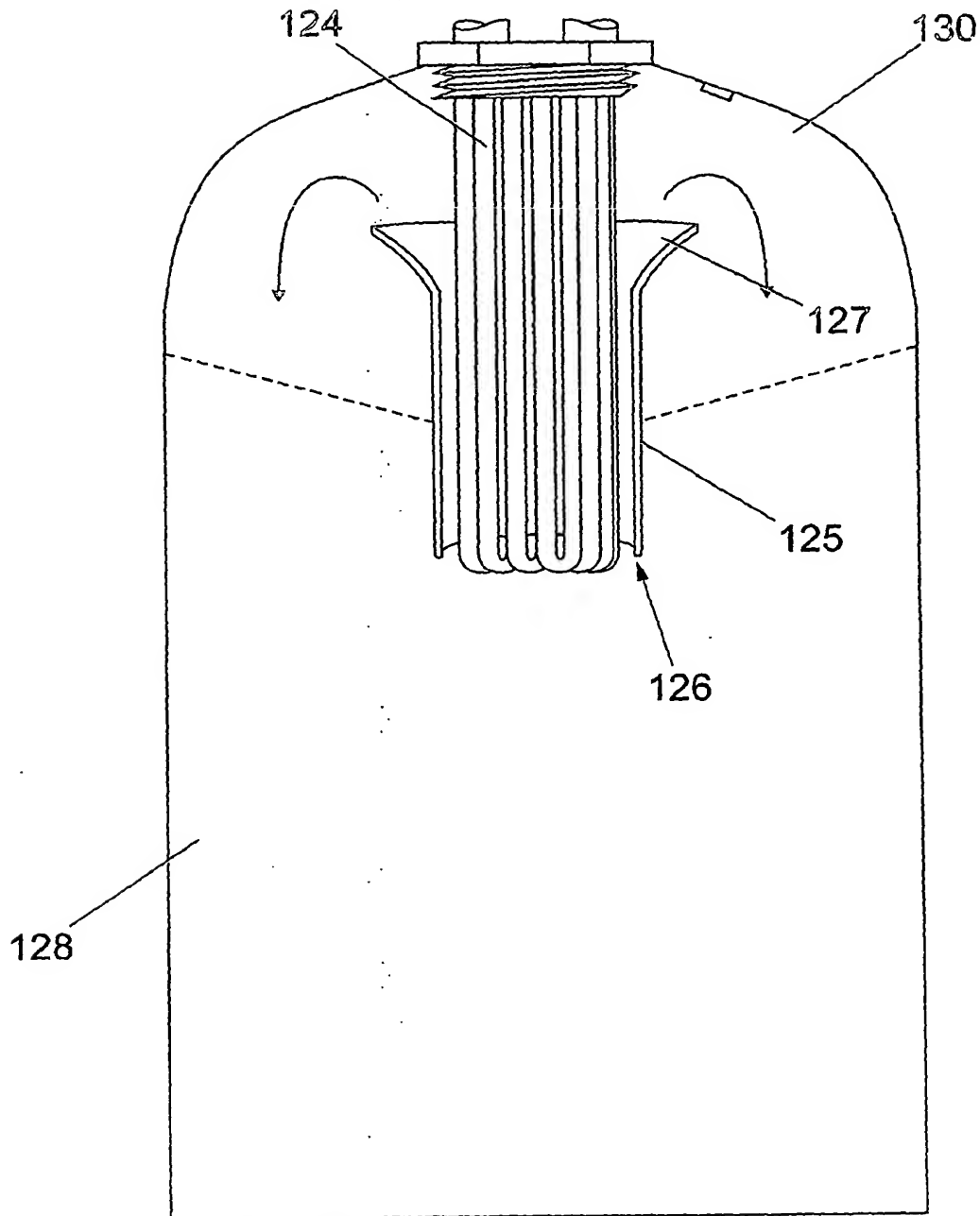
*Fig. 8a*

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*Fig. 8b*

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*Fig. 9a*

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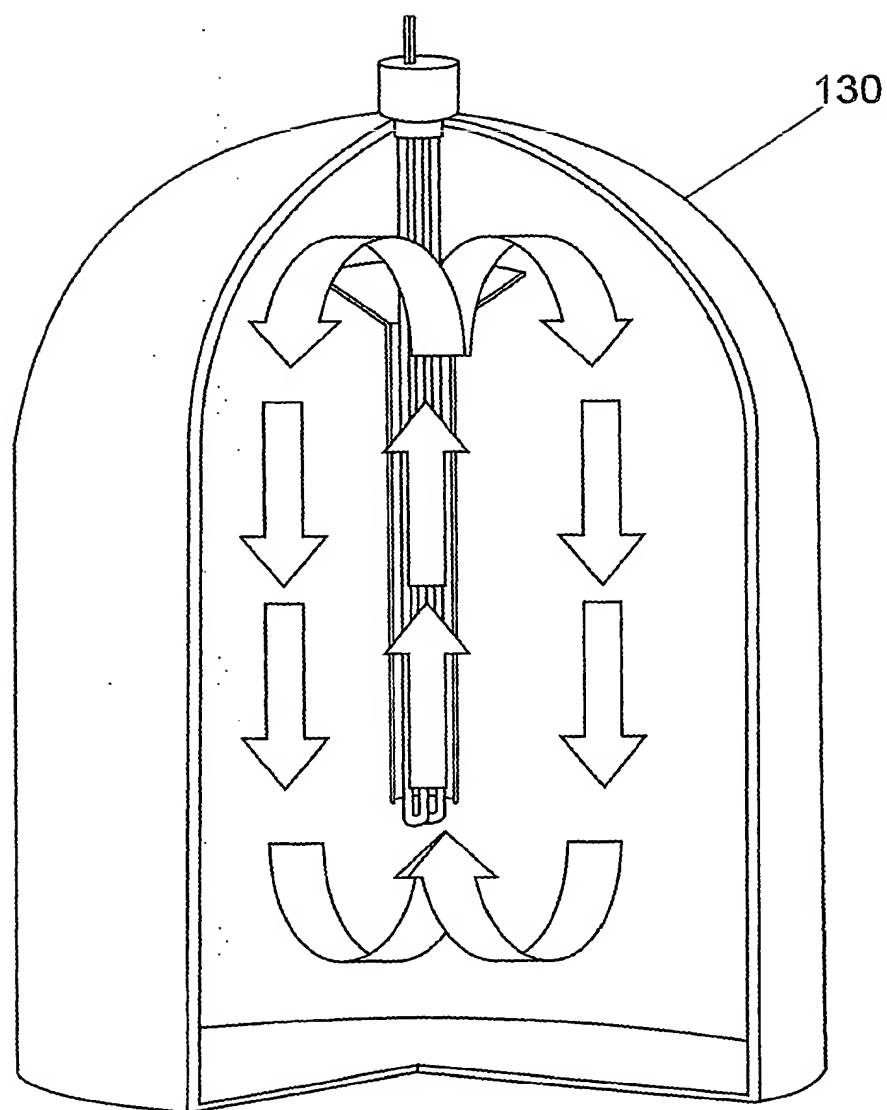
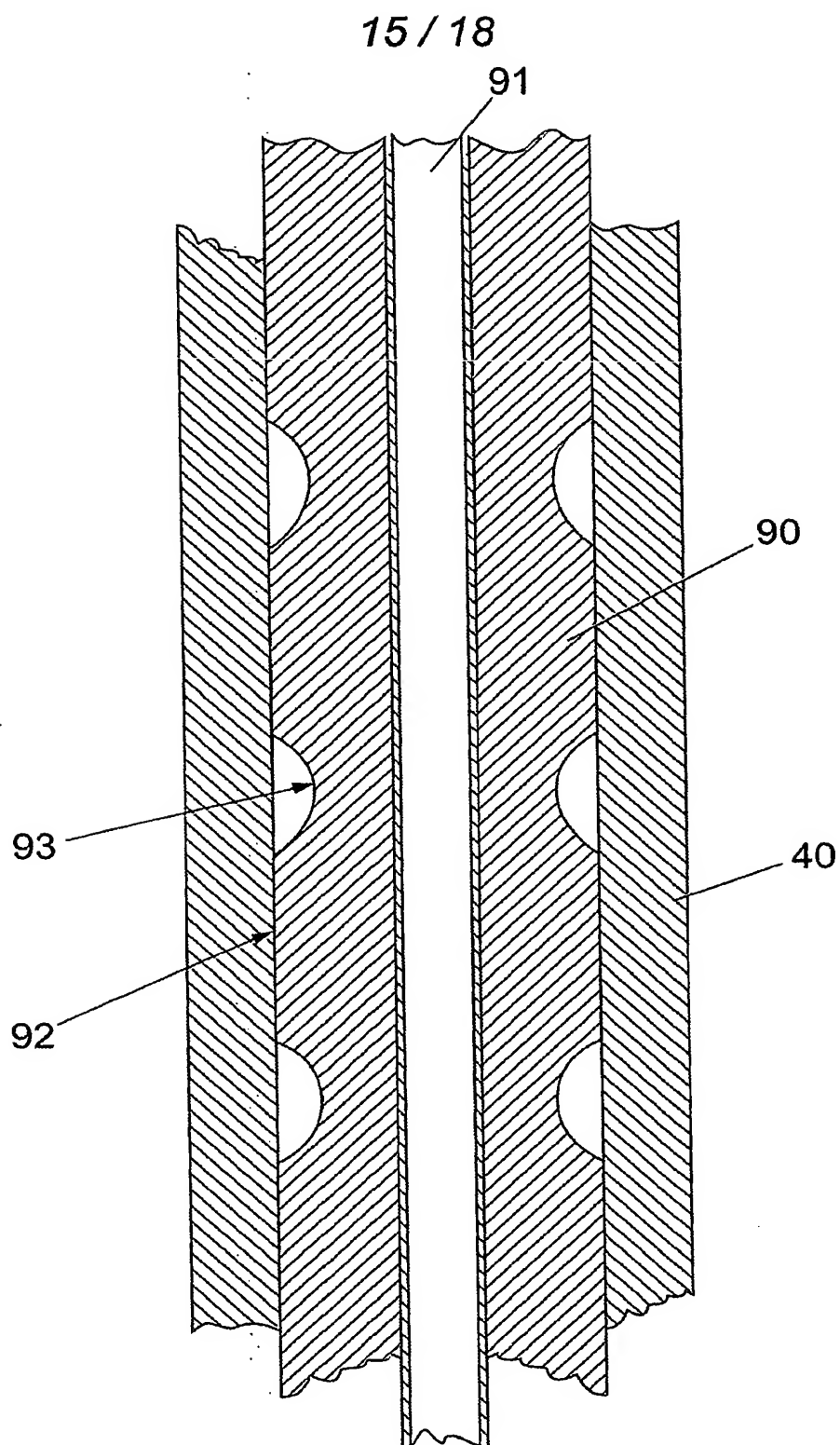
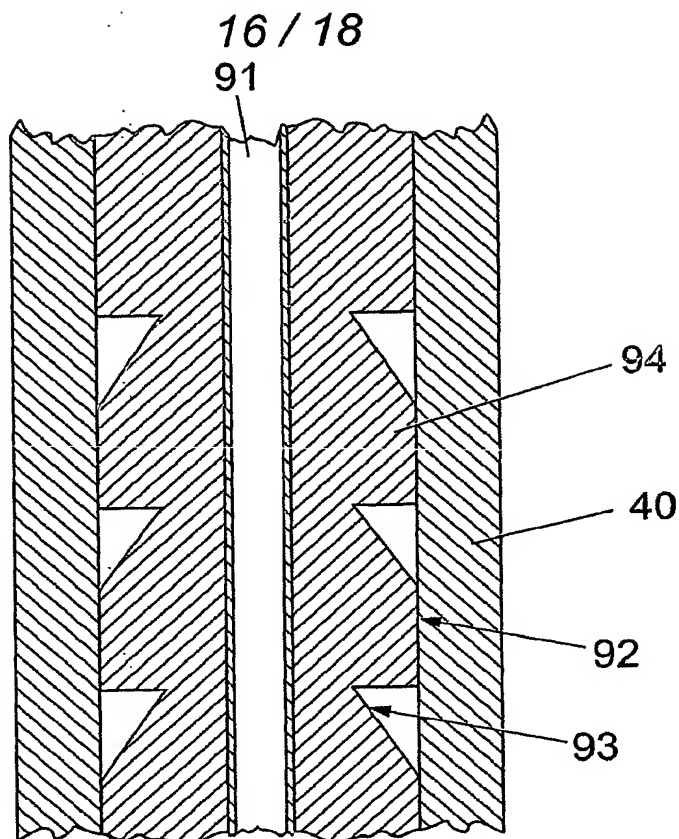


Fig. 9b

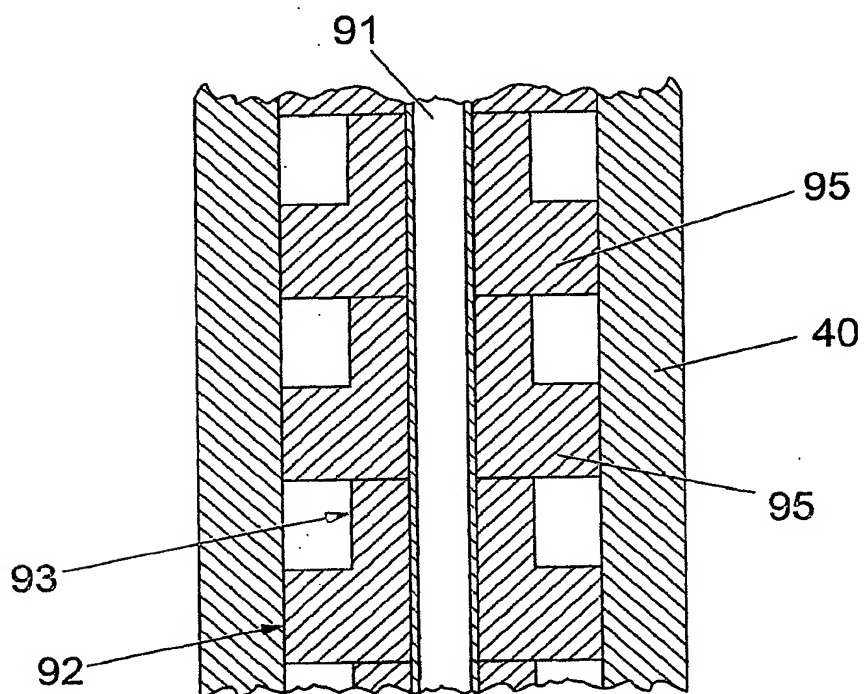


*Fig. 10*

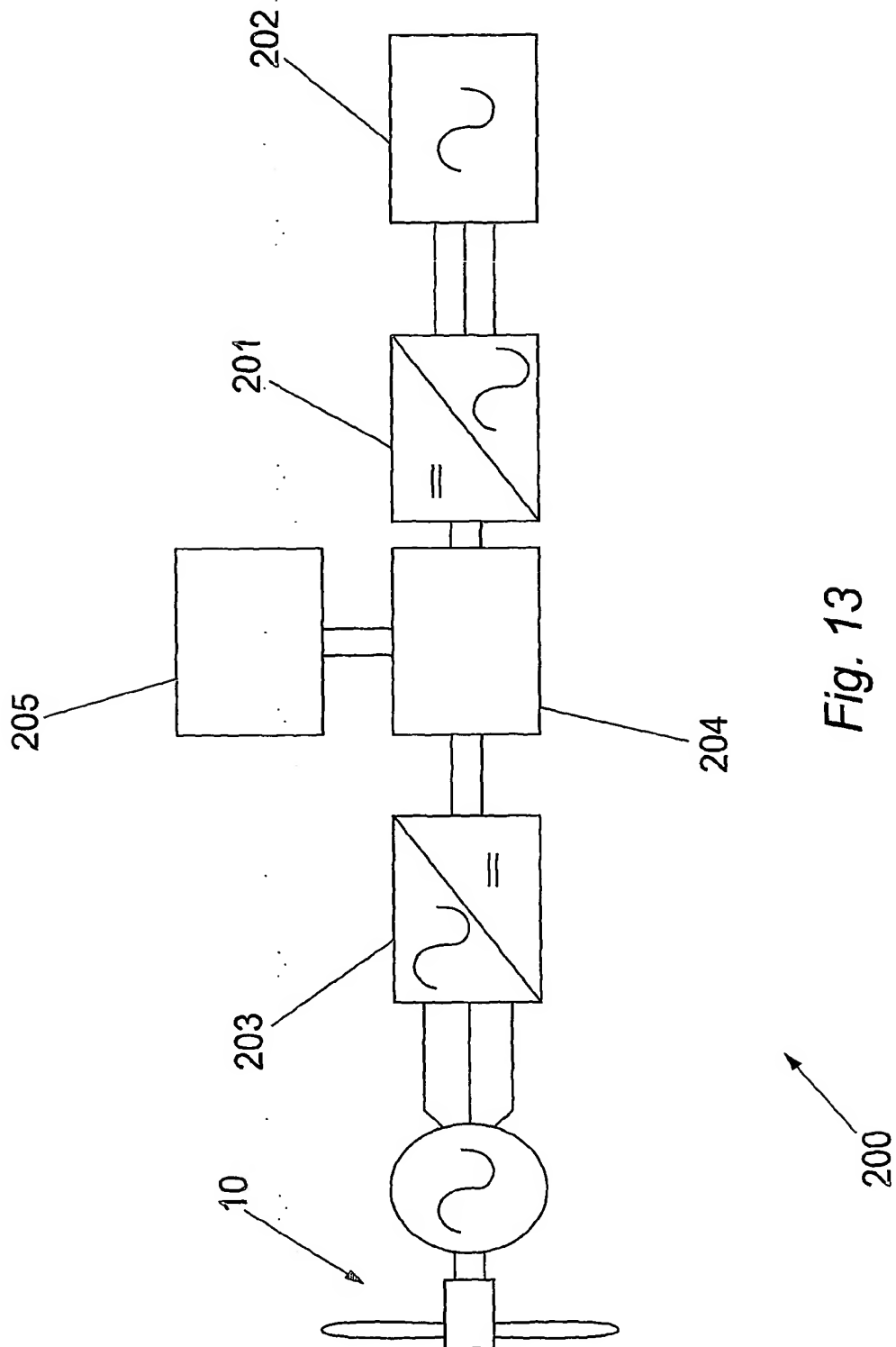
SUBSTITUTE SHEET (RULE 26)



*Fig. 11*



*Fig. 12*



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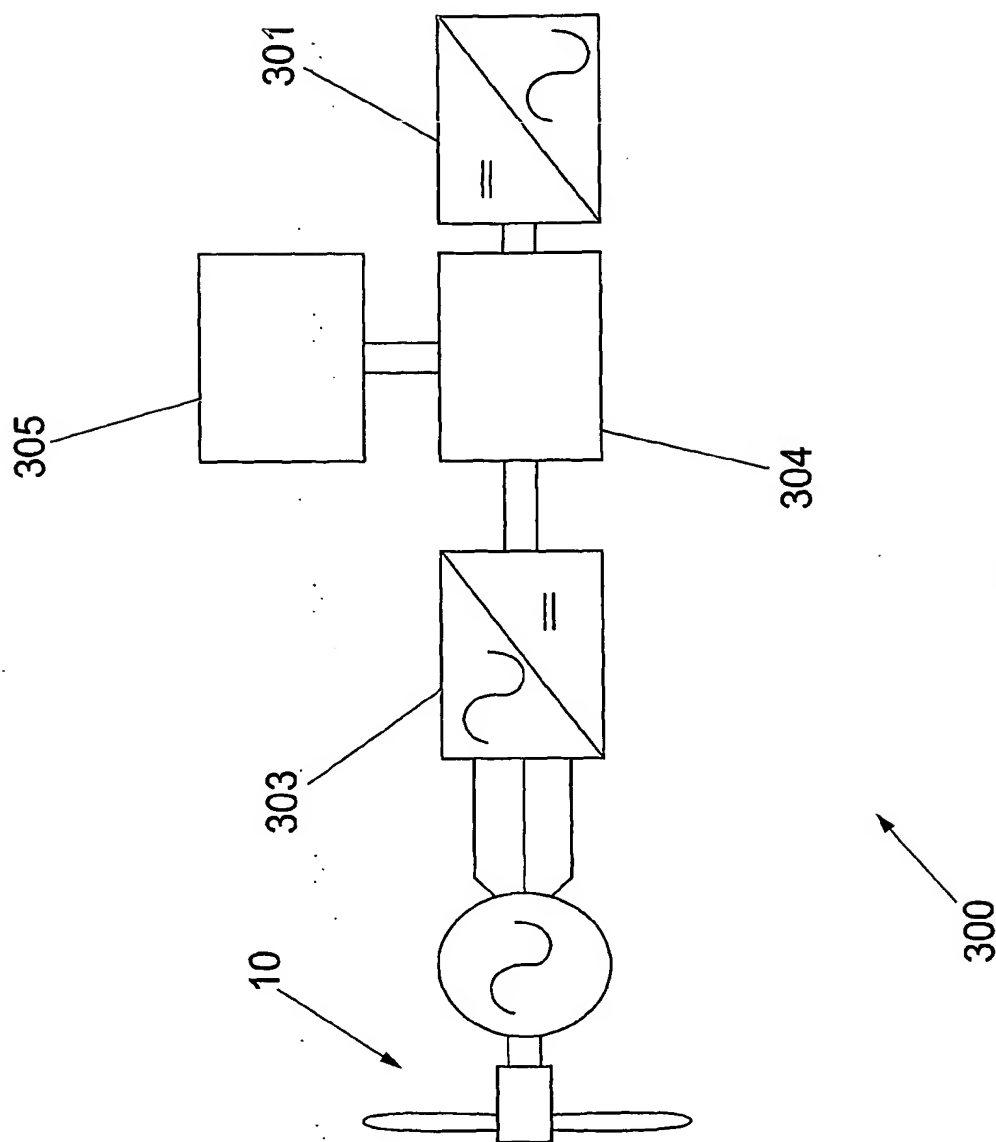


Fig. 14